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CASSIER'S MAGAZINE.

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PHILOSOPHY OF THE MULTIPLE-CYLINDER ENGINE.

By Professor R. H. Thurston, Director; Sibley College, Cornell University.



THE multiple-cylinder engine, which is most commonly, in its familiar forms, known as the compound, the triple-expansion, the quadruple-expansion, accordingly as it has two, three, or four cylinders "in series," constitutes one of the most effective of known devices for securing economy of steam and fuel by the reduction of what are called the avoidable wastes of the engine,—those which occur by defects in the real as distinguished from the ideal engine.

It is easy to compute the necessary expenditure of heat, of steam, and of fuel in the latter, which is, however, never capable of complete realization in practice. The ideal engine is only subject to what is denominated the necessary thermodynamic waste, that which results from the discharge into the atmosphere or into a condenser, of that portion of the heat supplied which, expansion having reached its limit, cannot be transformed into work, but remains, at the opening of the exhaust-valve, in the form of sensible heat and must be rejected as such. This fixed amount, in each case, and is measured in the best case by the proportion t_2 / t_1 of the total heat supplied, while the proportion transformed and utilized as power is, in the same case, always equal to $(t_1 - t_2) \div t_1$. The proportion rejected is greater, and that utilized is less, as the expansion is less complete and as the defects of practical construction and operation come into play. The wasted heat of the real engine consists of the necessary thermodynamic waste just referred to, of losses by conduction and radiation to external bodies, and of wastes by internal "cylinder condensation" produced by the alternate storage of heat in the metal of the cylinder at its entrance, and its restoration as heat and without useful transformation during the periods of later expansion and of exhaust. This latter constitutes the principal avoidable loss of the common forms of "simple" engine. Wastes by external disposition of heat are comparatively small, and can be reduced easily and conveniently to any extent that may be found desirable and on the whole economical; but these interior wastes are less easily checked, as no means of clothing or of rendering impervious to heat the interior surfaces of the cylinder have been devised.

The principles of economical operation and of construction of the engine with reference to the reduction of these wastes have been considered by all modern writers and need not be reviewed here; they all apply with equal force to the simple and to the compound or multiple-cylinder engine. The latter form of engine is a contrivance, not for reducing the waste in a single cylinder, but for making the wastes from one cylinder useful in the working of another in series with it.

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The principles to be observed in the design of the later type of engine are the following :

1. For any one cylinder there exists a limit beyond which it is not, on the whole, advisable to prolong expansion.

The gains are more than compensated by the losses, either measured on the balance-sheet representing expenditures of heat or on that which measures the money costs. The latter consideration places an earlier limit to expansion to the former, but both conspire to forbid the use of a ratio of expansion in a single cylinder of anything like the magnitude of that which would be dictated by purely thermodynamic considerations as illustrated by the action of steam in the ideal engine. There is therefore a certain ratio of expansion which is best for each case, and which the engineer must approximate, if he would secure most satisfactory results as measured by the requirements of the proprietor of the engine.

2. Wastes of heat and financial conditions being left out of consideration, the limit of the expansion economically advisable in the engine is found at a point at which the pressure of the expanding steam is just sufficient to overcome the back-pressure as shown by the indicator, plus the friction resistance of the engine, as shown by the difference between the indicated and the dynamometric or brake power.

Beyond this point more work is done in resistance than in the impulsion of the piston, and the net result is a waste of heat and loss of power. This point is commonly found to be, in the non-condensing engine, from 2 to 5 pounds above the atmosphere, and, in the condensing engine, something less than this in addition to the condenser-pressure measured from vacuum. It is generally considered that it should be practicable to expand profitably to an "absolute" pressure of about 20 pounds in the former and 6 to 10 pounds in the latter, the limit being affected, in the case of the condensing engine, by the temperature and pressure found economical in the condenser, which quantities increase as the boiler-pressure rises. If a condenser pressure of 10 pounds is taken for good multiple-cylinder engines, it will probably usually not be too low for the high boiler-pressures now standard.

3. The heat entering the low-pressure cylinder, or any preceding cylinder in a series, in any compound or multiple-cylinder engine, wherever that cylinder may be placed, is precisely equal in amount to the quantity leaving the boiler and entering the high-pressure cylinder *less* the amount transformed, earlier, into work.

Since the proportion condensed by loss of heat in its transformation into work is usually small, it thus follows that, of the steam entering any one cylinde in series, a very large part, nearly all, generally, must enter the next cylinder as steam. For, were it otherwise, heat must either be continuously extracted from or continuously stored in the cylinder through which the steam is passed. In the first case, the latter must become a refrigerator, in the latter a superheater. Hence, again, all steam condensed initially in the cylinder into which it is entered must be, later,—during the period of expansion or during that of exhaust, —completely re-evaporated. This results in the proposition that all heat passing through the series is supplied in as effective state to one cylinder as to another, each taking steam from the preceding cylinder in series with it precisely as if it were receiving it from a boiler at the same pressure, *except* that the gradual conversion of heat into work, as the steam passes, step by step, through the engine, produces more and more moisture, and gives to each successive cylinder wetter steam than was received by that which preceded it.

The true action of the multiple-cylinder is now easily perceived. It is subject only to the wastes, apparently, of a single cylinder,—of that one of the series which is itself most affected by wastes. The losses by internal condensation which would take place in a simple engine of equal total range of expansion, and working between the same extreme limits of temperature and pressure, which increase rapidly as that range is increased, are, in the multiple-cylinder engine, divided practically by the number of cylinders in series. This would indicate

that the greater the number of such cylinders, the better; but it must be remembered that each new element thus introduced brings with it increased wastes externally, more friction, greater cost, and that these factors, in turn, limit the number of cylinders advisable, in the very best examples of high economy, to a very small number. Experience shows that it is, on the whole, not advisable to increase the number beyond about one to each four or five atmospheres pressure; or, perhaps better, that the ratio of expansion should not exceed about three in any one cylinder, nor be less than two and a half. Thus it has been found by the best builders that the simple engine is best, as a rule, up to about 50 or 60 pounds per square inch, by gage, the two-cylinder or double expansion engine from that limit up to about 100 or 120, the triple-expansion up to 180 or 200, and the quadruple-expansion engine—four cylinders in series—beyond that point. Taking the limit of the expansion ratio at 3 and the terminal pressure at 10 pounds, and assuming hyperbolic expansion, we have the following as illustrating good practice, condensing engines being understood:

Engine.	Ratio, Total.	Ratio, Single.	Limit of Pressure.
Single cylinder	5	5	50 lbs.
" "	6	6	60 "
Double-expansion	9	3	90 "
Triple-expansion	27	3	270 "
Quadruple-expansion	81	3	810 "
Quintuple-expansion	243	3	2430 "

This would indicate that the four-cylinder engine is likely to answer all purposes up to quite as high a pressure as is ever to be expected to be used in the steam engine, so far as we can see, to-day.

The weights of steam and the quantities of heat demanded per horse power per hour for the ideal engine being computed, and the probable losses for the most wasteful cylinder of the series, the sum of the two quantities measures the probable demand, approximately, for the multiple-cylinder engine. The waste will be not far from one-half that for the simple engine in the case of the ordinary compound, one-third of that amount in the triple-expansion, one-fourth in the four-cylinder, and one-fifth in the quintuple-expansion engine. The computation of these quantities is comparatively easy, and that for the ideal engine may be made exact. The following is the general outline of the process of computation: The indicator diagram is the measure of the total quantity of heat converted into work in either the ideal engine or the real case. The quantity of heat necessarily supplied to insure the performance of that work is measured by the total heat of evaporation of the volume of steam demanded to fill the cylinder up to the point of cut-off, in the case of the ideal engine, and to this amount augmented by the sum of the heat-wastes in the case of the real engine. The quotient of the one of these quantities by the other, for either engine, is a measure of the efficiency of the working fluid for that engine. The tables found in every mechanic's pocketbook, and in all treatises upon the steam engine, furnish the data needed for this computation.

A perfect engine working under what are now usual practical conditions as to temperature and pressure of steam, and fully utilizing all heat, assuming it possible by conversion into mechanical energy without waste, thermodynamic or other, would need less than 2½ pounds of steam or of feed-water per horse power per hour. Dividing this quantity by the efficiency of the fluid, in any case, will give a measure of the required amount of steam or water for that case. Ordinarily good engines have an efficiency of about 10 per cent. and use about 25 pounds; the better class of existing engines has a thermodynamic efficiency of about 25 per cent., requiring about 10 pounds plus perhaps a third or a half more for wastes; while the cheaper and less economical engines of the market, especially in the smaller sizes, demand from twenty times the ideal amount, for efficiency unity, to fifty times that quantity, and even more. The following are weights and efficiencies for the cases assumed in the table as computed by the method first developed by Professor Rankine, and as given in his treatise on the steam engine, assuming 9 pounds evaporation per pound of fuel:

IDEAL STEAM ENGINE EFFICIENCIES.

PRESS. INITIAL.	LBS., B. P.	E.	R.	WEIGHTS, STEAM.	LBS., FUEL.
60	4	0.125	3.3	20.00	2.22
80	4	0.130	4.0	19.62	2.18
100	4	0.150	5.0	16.67	1.85
60	18	0.074	2.5	33.78	3.75
80	18	0.091	3.33	27.78	3.09
100	18	0.105	5.0	23.21	2.65
120	18	0.115	5.0	21.74	2.42
160	18	0.127	5.0	18 90	2.10

But the best of engines will waste much of the steam and heat supplied, and ordinary engines experience enormous losses, by internal and sensible wastes, by external conduction and by radiation. For the first of the above sets, the condensing engine, if of fair size and good construction, this waste may be fairly taken, for present purposes, at about 6 pounds of steam per horse power per hour, and for the non-condensing engines at about 10, making the total demand for steam and fuel larger than above given by those amounts; the fuel required being increased by two-thirds of a pound in the condensing, and a trifle over a pound in the non-condensing engines. Drier or superheated steam, higher piston speed, increased compression, smaller "dead spaces," will reduce these wastes, while the reverse conditions will increase them. Compounding the engine will reduce the losses, also, as the number of cylinders is increased, except that the additional mechanism will itself introduce wastes of heat and of power which may, and will, if carried far enough, counterbalance the thermodynamic and thermal gains. For a double-expansion engine the wastes should be reduced to 3 pounds of steam for the first set above, and to 5 for the second; triple-expansion should make these figures 2 and $3\frac{1}{3}$ pounds; quadruple-expansion approximately $1\frac{1}{2}$ and $2\frac{1}{2}$ pounds respectively. In other words, the compound engine should exhibit an economy of about 10 per cent. over the simple engine of equally good construction, the triple-expansion engine a gain of probably 15 per cent., the quadruple expansion a gain of 20 per cent., as minima and for the most perfect constructions, while the economy thus effected would be a higher percentage of the consumption of the simple engine, as that engine is the more wasteful. In ordinary work it is hence usual to see a gain of double that just stated, so that, in marine practice, the double-expansion engine shows a gain of about 20 per cent., and affords good returns on the cost of substitution; the triple-expansion often gains 15 per cent. upon the former, and the quadruple-expansion engine exhibits a gain of 10 per cent. upon even the last, thus still affording a margin for profit by its introduction into new ships. These advantages are less for stationary engines, as space and fuel have a lower value; but where fuel is costly it will usually pay to employ at least the double-expansion, and sometimes, with sufficiently high steam-pressure, the triple-expansion engine.

It is at once seen to be the fact that, where the adoption of a high expansion ratio is precluded by increasing wastes in the simple engine, the increase of that ratio may be found profitable when those wastes are reduced, as by the use of cylinders in series; and the extension of the new system proves a means of making available higher pressure and larger ratios of expansion than would otherwise be practicable and profitable. What the limit may prove to be is at present entirely a matter of conjecture; but that it is likely to be found at much higher pressures than are now common may be indicated by the following computation:

Let it be assumed that a quintuple-expansion engine is to be built, to work at 500 pounds per square inch; it is desired to know what may be anticipated as the probable consumption of steam and of fuel per horse power per hour. Taking the back-pressure at 5 pounds, the ratio of expansion desirable as $2.5^3 = 64.4$, and adopting Rankine's method of computation, we find that the ideal engine would require about 10,000 thermal units, 9.3 pounds of steam, or, say, one pound of best coal per horse power and per hour. Taking the wastes now usual and as measured, approximately, by the expression $c = 0.15\sqrt{r}$, for the simple engine, they would amount to 1.2 pounds, and the total expenditure would be about 2.2 pounds. If shared equally among the five cylinders, however, the

waste would be reduced to about a quarter of a pound for the real engine, and the total consumption of steam and of fuel would be about 12 pounds and 1.25 pounds respectively. It is at once evident that, where fuel is costly and engine-building comparatively inexpensive, the advantages of the high-expansion engine might compensate its greater cost as compared with the simpler types; but that where fuel is cheap or engine-building costly, the reverse result would follow. As the economy of the best class of engines increases about as the logarithm of their best ratios of expansion, it is further certain that additional gain must take place very slowly, and at questionable total economic advantage.

The result of experience in stationary engine operation indicates that the best "low-speed" engines with automatically adjustable valve-gear may be expected to give the horse power on an expenditure of about 2 pounds when condensing and 3 pounds if non-condensing. Compounding the former is found to bring down the expenditure to about 1.7, or less in some cases. Compounding the single-valve high-speed "automatic" engine reduces the consumption of fuel from about 3.5 or 4 pounds to 2.5 or 3, the best practice being considered, the gain being thus a larger percentage in the less economical class of motor. Triple-expansion will probably give added advantage, but its amount is, as yet, not determined, except approximately by computations such as have been described.

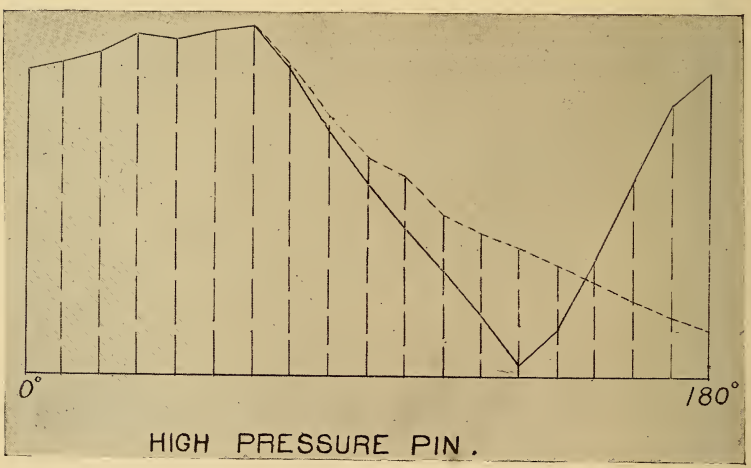
On the whole, as has been seen, the compound engine is an expedient, on the part of the designing engineer, for reducing the wastes which distinguish the steam engine, as actually constructed and operated, from the ideal toward which he continually aspires and which he constantly approximates as his knowledge and skill become more fruitful of result in effecting the approximation of the actual conditions of heat transformation to those ideal conditions which are assumed in the purely thermodynamic philosophy of the steam engine. Could these wastes, which characterize the faulty production of the builder, be entirely or approximately prevented, it is evident that this expedient would cease to have value, for the simple engine would then possess the thermodynamic efficiency of the most perfect possible compound engine, while it would be, in many forms at least, its superior in lightness, freedom from friction, and simplicity of construction, and consequent cheapness. The simple engine has a single cylinder equal in magnitude to a single one—the low-pressure cylinder—of the mutiple-cylinder engine, and it requires no more than a single set of the working members of the machine, where the other needs a set for each of its several lines of synchronous reciprocation. Two cranks, or even three, may often be found essental to best effect, even with the simple engine; but this is not always the fact, and where it is an essential the simple engine is still in some respects superior to the multiple-cylinder machine. Should the time ever come, therefore, when the steam engine can be made free from heat-wastes, or approximately so, we may expect a return to the simple type.

In some cases the simple engine has actually been operated with such small loss of heat and of friction work, even now, that many engineers retain a conviction that it is often perfectly possible to secure, on the whole, as good service from the older type as from the latest of the compound styles. This is not at present, however, accordant either with general opinion or with usual experience.

EFFECT OF COMPRESSION UPON SHAFT FRICTION IN A TRIPLE-EXPANSION ENGINE.

By Geo. I. Alden, M.M.E.

THE extraordinary increase during the last decade in the development and use of power has led to a careful study of every source of loss or waste of energy in the steam engine. One source of such loss is friction. The energy expended in overcoming the friction of the engine disappears as mechanical energy, being transformed by the friction into heat. Whatever reduction can be made in friction by lubrication and good workmanship, is a clear gain not only of the energy saved, but usually a gain also in the commercial efficiency of the engine, by diminishing cost for wear and by lengthening the life of the machine. But with the best workmanship and lubrication there may be variations in the design of an engine which affect the total friction of the engine. The writer recently designed an upright triple engine for the engineering laboratory of the Worcester Polytechnic Institute, and as the design involved an unusual amount of compression or "cushioning" the question was raised whether the compression might not increase the shaft friction of the engine. As an answer to this question seemed to involve considerable computation of a somewhat complex character, the matter was referred to Mr. Arthur L. Rice, who made the required calculations for the particular engine in question, and reported his work in June, 1891, as a graduating thesis. The general outline of the work done and the results obtained by Mr. Rice may be of interest not only on account of the importance of reducing engine friction, but also as being the first published data on this question, so far as the writer is aware. Such outline and data are given below. It is not the purpose of this article to give the mathematical work required in the solution of the problem, but it may be well to note a few general facts relat-



HIGH PRESSURE PIN.

ing to the effect of compression upon the pressure exerted on the crank-pins and bearings of the engine-shaft at its various angular positions.

If it were not for the action of the reciprocating parts,—piston, connecting-rod, and cross-head,—the effect of closing the exhaust before the end of the stroke would be to put back pressure on the crank-pin, and thus cause additional friction. But as these heavy moving parts must be stopped at the end of each stroke, if there is no cushioning, the force to stop them must be exerted through the crank-pin and thus cause additional pressure both upon the crank-pin and the bearings of the shaft. When compression is used and rightly adjusted to the weight of the reciprocating parts, the force stopping these parts is transmitted through the *frame* of the engine to the engine-bed, instead of through the crank-pin and shaft. It would, therefore, seem as if compression might be used to reduce shaft friction. In the engine under consideration there are three cranks upon one shaft, the cranks being 120° apart. The cylinders and pistons are so arranged that the pistons act as valves between the cylinders, and the steam passages between cylinders are direct. The whole friction on the shaft at any instant being due to the resultant of a complicated system of forces, no general conclusions as to the effect of the high degree of compression used could be relied upon.

The method pursued in the solution of the problem was :

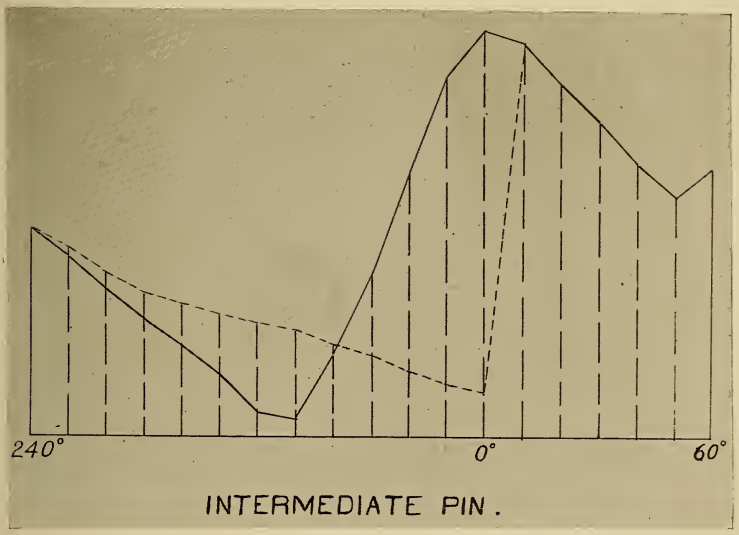
1. To compute clearances which for the given exhaust closures would bring the compression in each cylinder up to the initial pressure to be used in that cylinder.

2. To locate the positions of the high-pressure piston for every ten degrees advance of the crank during forward stroke.

3. To locate the corresponding positions of the intermediate and low-pressure pistons.

4. To compute the pressures on each crank-pin, first with compression, and second without compression, taking into account the effect of the reciprocating parts.

5. To find the pressure on the bear-



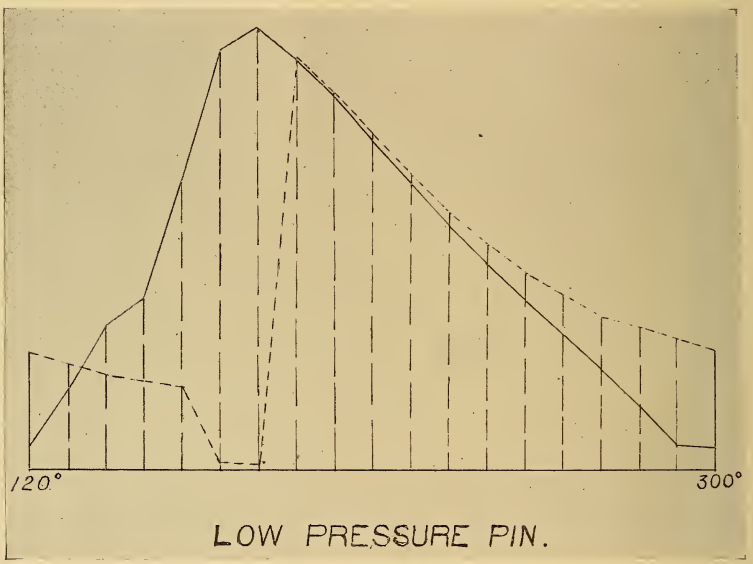
ings of the shaft, due to the pressures on the three crank-pins.

6. Assuming a coefficient of friction, to find the work of the friction with compression and without compression, and compare the results.

In fixing the clearances, the initial steam pressure in the high-pressure cylinder was assumed to be 200 pounds absolute, and the pressure in condenser was assumed at about 6 pounds.

Since steam for the engine is to be furnished by a Babcock & Wilcox boiler made expressly for the engineering laboratory of the institute, and carrying with entire safety 200 pounds pressure or more, the engine was designed to work with this high pressure, which may be considered as a limit toward which practice is rapidly approaching. The superior efficiency of compound and triple engines is partly due to the wide range of pressures used, and the fact of this superior economy is compelling builders to compound their engines, so that it is not improbable that the use of 200 pounds steam pressure may become common at no distant day.

In locating the piston positions for each ten degrees of the forward stroke of the high-pressure piston, it was assumed that the friction on the return stroke would be so nearly the same as that on the forward stroke that only the latter need be calculated. The work of computing the pressures upon the crank-pins was quite long and tedious, and the methods and formulæ are not given in this article, but the reader interested in the solution of a similar problem for any given engine will find the processes explained in Professor Unwin's "Elements of Machine Design," or in a paper by the writer published in the Transactions of the American Society of Mechanical Engineers, Vol. VIII, page 191.



LOW PRESSURE PIN.

The coefficient of friction for a shaft or crank-pin in actual use probably varies from 3 to 10 per cent. In experiments recently made by Professor Carpenter at the Sibley College laboratory, 4 per cent. was the lowest coefficient obtained for shaft friction with the engine under its working load, while in some cases the coefficient was as high as 9 per cent.

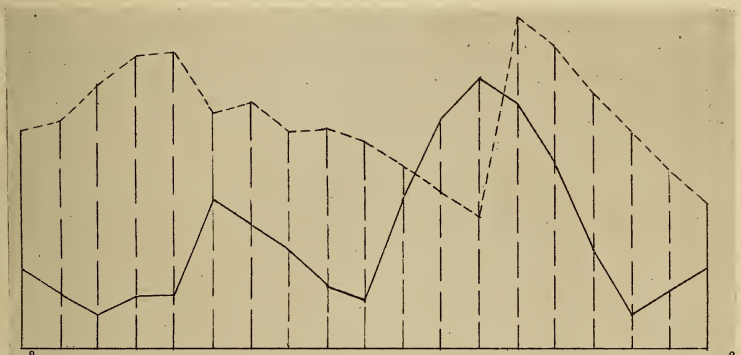
It is probable that the friction on the crank-pins is less for a given pressure than on the bearings of the shaft, since on the former the pressure changes in direction and thus gives better opportunity for lubrication.

The accompanying diagrams show the results obtained. In each of the diagrams the base line represents the rectified semi-circumference of a crank-pin or of the crank-shaft. The eighteen equal divisions of the base line each represent ten degrees on the rectified half-circle. The crank-angles, marked in degrees at the ends of each base line, are reckoned from the position of the high-pressure crank at the beginning of the forward stroke. The ordinates terminating in the full broken lines represent the force of friction upon the crank-pin or shaft when the engine runs with full compression, while the ordinates terminating in the dotted lines represent the force of friction when running without compression.

Areas upon the diagrams represent work done in overcoming friction. Assuming 7 per cent. as the coefficient of friction and 3½ inches for the diameter of shaft and pins, the scale of the diagrams is as follows: Horizontal scale, one inch $= \frac{1}{10}$ feet nearly; vertical scale, one inch = 100 pounds.

Then one square inch on the diagram is equal to about 10 foot-pounds of work or energy. An analysis of these diagrams shows not only the effect of excessive compression in this engine, but also indicates that *moderate* compression would have been still more advantageous in diminishing friction.

Take, for example, the diagram for the intermediate pin. While it shows a loss due to compression, this loss clearly arises from the fact that there was much more compression than enough to arrest the reciprocating parts; otherwise the full line would have remained below the dotted line, and the diagram would have shown a diminution of friction by *well-adjusted* compression.

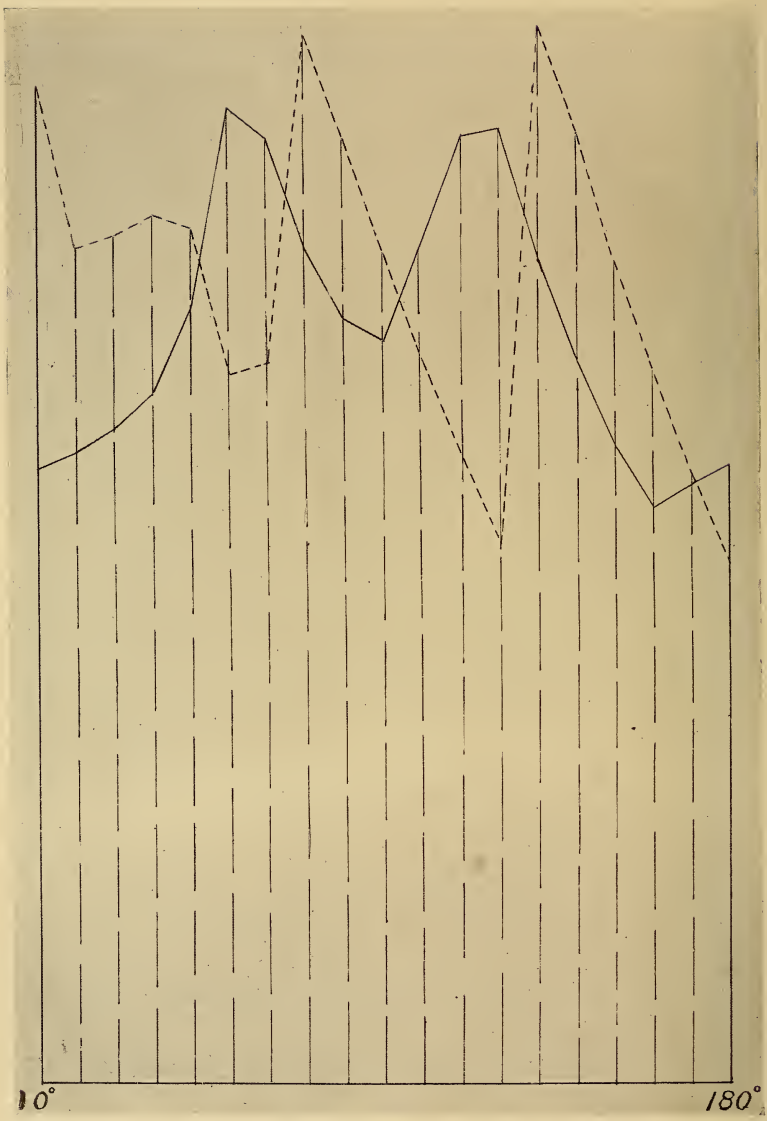


MAIN SHAFT.

The diagram for the main shaft shows a very great saving from compression, the friction being less than one-half as much with compression as without, and while a part of this gain is counterbalanced by losses at the crank-pins, it should be remembered that, as just shown, these losses at the crank-pins are due to *excessive* compression,—that is, more compression than is required to bring to rest the reciprocating parts.

The total result is shown in the last diagram, which is made by combining for each crank-angle the frictions on the pins and shaft.

It appears that the friction is more nearly uniform with compression than



TOTAL.

without, there being less difference between the maximum and minimum ordinates of the full than of the dotted line. With 300 revolutions per minute and a coefficient of friction of 7 per cent., the horse power required to overcome friction is: with compression, 4.37; without, 4.13, or a saving by compression of 5½ per cent. of the total friction.

These results show that even with the high degree of compression used there is certainly no increase of friction, but rather a small diminution; and as the engine will work with considerable less compression than was assumed in these calculations, it is reasonable to conclude that so far as shaft friction is concerned this engine will, on account of the special features of its design, by which a considerable degree of compression is necessary, be more efficient than the same engine running without compression; and it seems quite probable that an application to engines of various types of the analysis above outlined may show that in general, suitable compression in an engine results in increasing the efficiency of the engine by diminishing the total engine friction.

THE COAL PRODUCTION.

141,229,513 TONS.—According to the census bulletin just issued there were 141,229,513 short tons of coal produced in the United States during the census year. It was valued at the mines at $160,226,323. The product included 45,600,487 short tons of Pennsylvania and other anthracite, worth $65,879,514, and 95,629,026 short tons of bituminous and lignite, valued at $94,346,809. In 1880 the total product included 28,649,812 short tons of anthracite and 42,831,758 short tons of bituminous coal, valued at $95,640,396. The product increased 97.57 per cent. during the decade and the value 67.53 per cent. The total number of persons engaged in the industry was 299,559, who received an aggregate of $109,130,928 in wages.

JOHN DEANE BENTON.

JOHN DEAN BENTON, machinist, inventor, and bosom friend of John Ericsson, died a few months ago in East Providence, R.I. He was born in Fort Independence, Boston, sixty-seven years ago, his father, Major Benton, being commandant. He was in the war. Rheumatism deformed his hands and feet, so that he could not follow his trade as jeweler. He set to work making models, and in all turned out 125 different working automata of the nickle-in-the-slot order. He made the silver model of the Corliss engine which was on exhibition at the Centennial in 1876, and also that of Independence Hall, which is now in Washington. He made six or seven models of ships in gold and silver for General Morgan, of New York, and there are a great many models about the country from which he derived a large income. He once won $100,000 in the Havana Lottery. Benton was ordered by Ericsson's friends to build a model of the Monitor in gold and silver, to be presented to Ericsson. When he tried to present it to the Swedish commodore he met with a cold reception. The music box then began to play the familiar airs of Ericsson's fatherland, when the scientist burst into tears. An unbroken and close friendship resulted.

TWO HUNDRED AND FIFTY TON CLOUD.

A LONDON paper recently stated that it was estimated that the great smoke cloud which sometimes hangs over London weighs 300 tons, 50 tons of which are solid carbon and 250 tons hydrocarbon. It is calculated that the smoke of the year is worth two millions sterling, or ten million dollars.

EARLY HISTORY OF THE STEAM ENGINE.

THE earliest notices of heat engines are found in the *Pneumatica* of Hero of Alexandria (*c.* 130 B.C.) Two contrivances described there deserve mention. One is the æolipile, a steam reaction-turbine consisting of a spherical vessel pivoted on a central axis and supplied with steam through one of the pivots. The steam escapes by bent pipes facing tangentially in opposite directions, at opposite ends of a diameter perpendicular to the axis. The globe revolves by reaction from the escaping steam, just as a Barker's mill is driven by escaping water. Another apparatus described by Hero (Fig. 1) is

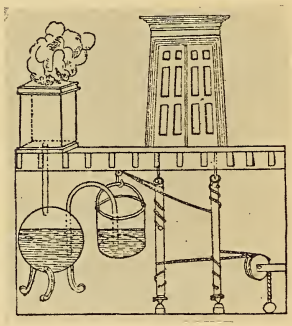


FIG. 1.—HERO'S APPARATUS, 130 B.C.

interesting as the prototype of a class of engines which long afterward became practically important. A hollow altar containing air is heated by a fire kindled on it; the air in expanding drives some of the water contained in a spherical vessel beneath the altar into a bucket, which descends and opens the temple doors above by pulling around a pair of vertical posts to which the doors are fixed. When the fire is extinguished the air cools, the water leaves the bucket, and the doors close. In another device a jet of water driven out by expanding air is turned to account as a fountain.

From the time of Hero to the seventeenth century there is no progress to record, though here and there we find evidence that appliances like those described by Hero were used for trivial purposes, such as organ-blowing and the turning of spits. The next distinct step was the publication in 1601 of a treatise on pneumatics by Giovanni Battista della Porta, in which he shows an apparatus similar to Hero's fountain, but with steam instead of air as the displacing fluid. Steam generated in a separate vessel passes into a closed chamber containing water, from which a pipe (open under the water) leads out. He also points out that the condensation of steam in the closed chamber may be used to produce a vacuum and suck up water from a lower level. In fact, his suggestions anticipate very fully the engine which a century later became in the hands of Savery the earliest commercially successful steam engine. In 1615, Solomon de Caus gives a plan of forcing up water by a steam fountain which differs from Della Porta's only in having one vessel serve both as boiler and as displacement-chamber, the hot water being itself raised.

Another line of invention was taken by Giovanni Branca (1629), who designed an engine shaped like a water-wheel, to be driven by the impact of a jet of steam on its vanes, and, in its turn, to drive other mechanism for various useful purposes. But Branca's suggestion was unproductive, and we find the course of invention revert to the line followed by Della Porta and De Caus.

The next contributor is one whose place is not easily assigned. To Edward Somerset, second marquis of Worcester, appears to be due the credit of making the first useful steam engine. Its object was to raise water, and it worked probably like Della Porta's model, but with a pair of displacement-chambers, from each of which alternately water was forced by steam from an independent boiler, or perhaps by applying heat to the chamber itself, while the other vessel was allowed to refill. Lord Worcester's

description of the engine in his *Century of Inventions* (1663) is obscure, and no drawings are extant. It is therefore difficult to say whether there were any distinctly novel features except the double action; in particular it is not clear whether the suction of a vacuum was used to raise water, as well as the direct pressure of steam. An engine of about two horse power was in use at Vauxhall in 1656, and the walls of Raglan Castle contain traces of another, but neither Worcester's efforts nor those of his widow were successful in securing the commercial success of his engine.

This success was reserved for Thomas

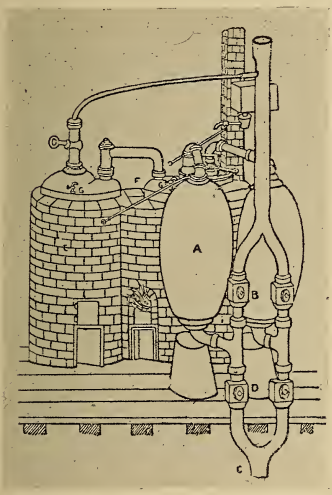


FIG. 2.—SAVERY'S PUMPING-ENGINE, 1698.

Savery, who in 1698 obtained a patent for a water-raising engine, shown in Fig. 2. Steam is admitted to one of the oval vessels A, displacing water, which it drives up through the check-valve B. When the vessel A is emptied of water, the supply of steam is stopped, and the steam already there is condensed by allowing a jet of cold water from a cistern above to steam over the outer surface of the vessel. This produces a vacuum and causes water to be sucked up through the pipe C and the valve D. Meanwhile, steam has been displacing water from the other vessel, and is ready to be condensed there. The valves B and D open only upward. The supplementary boiler and furnace E are for feeding water to the main boiler; E is filled while cold and a fire is lighted under it; it then acts like the vessel of De Caus in forcing a supply of feed-water into the main boiler F. The gage-cocks G, G are an interesting feature of detail. Another form of Savery's engine had only one displacement-chamber and worked intermittently. In the use of artificial means to condense the steam, and in the application of the vacuum so formed to raise water by suction from a level lower than that of the engine, Savery's engine was probably an improvement on Worcester's; in any case, it found what Worcester's engine had failed to find,—considerable employment in pumping mines and in raising water to supply houses and towns, and even to drive water-wheels. A serious difficulty which prevented its general use in mines was the fact that the height through which it would lift water was limited by the pressure the boiler and vessels could bear. Pressures as high as 8 or 10 atmospheres were employed,—and that, too, without a safety-valve,—but Savery found it no easy matter to deal with high-pressure steam; he complains that it melted his common solder, and forced him, as Desaguliers tells us, "to be at the pains and charge to have all his joints soldered with spelter." Apart from this drawback the waste of fuel was enormous, from the condensation of steam which took place on the surface of the water and on the sides of the displacement-chamber at each stroke; the consumption of coal was, in proportion to the work done, some twenty times greater than in a good modern steam engine. In a tract called *The Miner's Friend*, Savery alludes thus to the alternate heating and cooling of the water-vessel: "On the outside of the vessel you may see how the water goes out as well as if the vessel were transparent, for so far as the steam continues within the vessel, so far is the vessel dry without, and so very hot as scarce to endure the least touch of the hand. But as far as the water is, the said vessel will be cold and wet where any water has fallen on it; which

cold and moisture vanishes as fast as the steam in its descent takes place of the water." Before Savery's engine was entirely displaced by its successor, Newcomen's, it was improved by Desaguliers, who applied to it the safety-valve (invented by Papin), and substituted condensation by a jet of cold water within the vessel for the surface condensation used by Savery.

So early as 1678 the use of a piston and cylinder (long before known as applied to pumps) in a heat engine had been suggested by Jean Heautefeuille, who proposed to use the explosion of gunpowder either to raise a piston or to force up water, or to produce, by the subsequent cooling of the gases, a partial vacuum into which water might be sucked up. Two years later Huygens described an engine in which the explosion of gun-

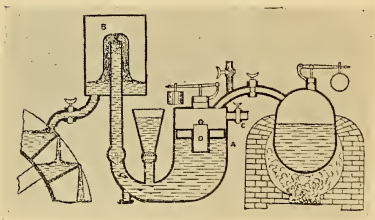


FIG. 3.—PAPIN, 1705.

powder in a cylinder expelled part of the gaseous contents, after which the cooling of the remainder caused a piston to descend under atmospheric pressure, and the piston in descending did work by raising a weight.

In 1690, Denis Papin, who ten years before had invented the safety-valve as an adjunct to his "digester," suggested that the condensation of steam should be employed to make a vacuum under a piston previously raised by the expansion of the steam. Papin's was the earliest cylinder and piston steam engine, and his plan of using steam was that which afterward took practical shape in the atmospheric engine of Newcomen. But his scheme was made unworkable by the fact that he proposed to use but one vessel as both boiler and cylinder. A small quantity of water was placed at the bottom of a cylinder and heat was applied. When the piston had risen the fire was removed, the steam was allowed to cool, and the piston did work in its down-stroke under the pressure of the atmosphere. After hearing of Savery's engine in 1705, Papin turned his attention to improving it, and devised a modified form, shown in Fig. 3, in which the displacement-chamber A was a cylinder, with a floating diaphragm or piston on the top of the water to keep the water and steam from direct contact with one another. The water was delivered into a closed air-vessel B, from which it issued in a continuous stream against the vanes of a water-wheel. After the steam had done its work in the displacement-chamber it was allowed to escape by the stop-cock C instead of being condensed. Papin's engine was in fact a non-condensing single-acting steam-pump, with steam-cylinder and pump-cylinder in one. A curious feature of it was the heater D, a hot mass of metal placed in the diaphragm for the purpose of keeping the steam dry. Among the many inventions of Papin was a boiler with an internal fire-box,—the earliest example of a construction that is now almost universal.

While Papin was thus going back from his first notion of a piston engine to Savery's cruder type, a new inventor had appeared who made the piston engine a practical success by separating the boiler from the cylinder and by using (as Savery had done) artificial means to condense the steam. This was Newcomen, who in 1704, with his assistant, Cawley, gave the steam engine the form shown in Fig. 4. Steam admitted from the boiler to the cylinder allowed the piston to be raised by a heavy counterpoise on the other side of the beam. Then the steam valve was shut and a jet of cold water entered the cylinder and condensed the steam. The piston was consequently forced down by the pressure of the atmosphere and did work on the pump. The next entry of steam expelled the condensed water from the cylinder through an escape-valve. The piston was kept tight by a layer of water on its upper surface. Condensation was at first effected by cooling the outside of the cylinder, but the accidental leakage of the packing water past the piston

showed the advantage of condensing by a jet of injection water, and this plan took the place of surface condensation. The engine used steam whose pressure was little if at all greater than that of the atmosphere; sometimes, indeed, it was worked with the manhole-lid off the boiler.

About 1711 Newcomen's engine began to be introduced for pumping mines; and in 1713 a boy named Humphrey Potter, whose duty it was to open and shut the valves of an engine he attended, made the engine self-acting by causing the beam itself to open and close the valves by suitable cords and catches. Potter's rude device was simplified in 1718 by Henry Beighton, who suspended

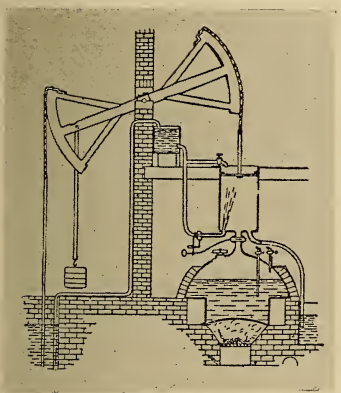


FIG. 4.—NEWCOMEN'S ATMOSPHERIC ENGINE, 1705.

from the beam a rod called the plug-tree, which worked the valves by means of tappets. By 1725 the engine was in common use in collieries, and it held its place without material change for about three-quarters of a century in all. Near the close of its career the atmospheric engine was much improved in its mechanical details by Smeaton, who built many large engines of this type about the year 1770, just after the great step which was to make Newcomen's engine obsolete had been taken by James Watt.

Compared with Savery's engine, Newcomen's had (as a pumping-engine) the great advantage that the intensity of pressure in the pumps was not in any way limited by the pressure of the steam. It shared with Savery's, in a scarcely less degree, the defect already pointed out,—that steam was wasted by the alternate heating and cooling of the vessel into which it was led. Though obviously capable of more extended uses, it was in fact almost exclusively employed to raise water—in some instances for the purpose of turning water-wheels to drive other machinery. Even contemporary writers complain of its "vast consumption of fuel," which appears to have been scarcely smaller than that of the engine of Savery.

In 1763, James Watt, an instrument-maker in Glasgow, while engaged by the university in repairing a model of Newcomen's engine, was struck with the waste of steam to which the alternate chilling and heating of the cylinder gave rise. He saw that the remedy, in his own words, would lie in keeping the cylinder as hot as the steam that entered it. With this view he added to the engine a new organ,—an empty vessel separate from the cylinder, to which the steam should be allowed to escape from the cylinder, to be condensed there by the application of cold water, either outside or as a jet. To preserve the vacuum in his condenser he added a pump called the air-pump, whose function was to pump from it the condensed steam and water of condensation, as well as the air which would otherwise accumulate by leakage or by being brought in with the steam or with the injection water. Then, as the cylinder was no longer used as a condenser, he was able to keep it hot by clothing it with non-conducting bodies, and in particular by the use of a *steam jacket*, or layer of hot steam between the cylinder and an external casing. Further, and still with the same object, he covered in the top of the cylinder, taking the piston-rod out through a steam-tight stuffing-box, and allowed steam instead of air to press upon the piston's upper surface. The idea of using a separate condenser had no sooner occurred to Watt than he put it to the test by constructing the apparatus shown in Fig. 5. There A is the cylinder, B a surface condenser, and C the air-pump. The cylinder was filled with steam above the piston, and a vacuum was formed in the surface condenser B. On opening

the stop-cock D, the steam rushed over from the cylinder and was condensed, while the piston rose and lifted a weight. After several trials, Watt patented his improvements in 1769; they are described in his specification in the following words, which, apart from their immense historical interest, deserve careful study as a statement of principles which to this day guide the scientific development of the steam engine:

"My method of lessening the consumption of steam, and consequently fuel, in fire-engines, consists of the following principles:

"First, That vessel in which the powers of steam are to be employed to work the engine, which is called the cylinder in common fire-engines, and which I call the steam vessel, must, during the whole time the engine is at work, be kept as hot as the steam that enters it; first, by enclosing it in a case of wood, or any other materials that transmit heat slowly;

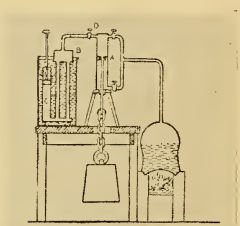


FIG. 5.—WATT'S EXPERIMENTAL APPARATUS.

secondly, by surrounding it with steam or other heated bodies; and, thirdly, by suffering neither water nor any other substance colder than the steam to enter or touch it during that time.

"Secondly, In engines that are to be worked wholly or partially by condensation of steam, the steam is to be condensed in vessels distinct from the steam vessels or cylinders, although occasionally communicating with them; these vessels I call condensers; and, whilst the engines are working, these condensers onght at least to be kept as cold as the air in the neighborhood of the engines by application of water or other cold bodies.

"Thirdly, Whatever air or other elastic vapor is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam vessels or condensers by means of pumps, wrought by the engines themselves, or otherwise.

"Fourthly, I intend in many cases to employ the expansive force of steam to press on the pistons, or whatever may be used instead of them, in the same manner in which the pressure of the atmosphere is now employed in common fire-engines. In cases where cold water cannot be had in plenty, the engines may be wrought by this force of steam only, by discharging the steam into the air after it has done its office. . . .

"Sixthly, I intend in some cases to apply a degree of cold not capable of reducing the steam to water, but of contracting it considerably, so that the engines shall be worked by the alternate expansion and contraction of the steam.

"Lastly, Instead of using water to render the pistons and other parts of the engine air- and steam-tight, I employ oils, wax, resinous bodies, fat of animals, quicksilver, and other metals in their fluid state."

The fifth claim was for a rotary engine, and need not be quoted here.

The "common fire-engine" alluded to was the steam engine, or, as it was more generally called, the "atmospheric" engine of Newcomen. Enormously important as Watt's first patent was, it resulted for a time in the production of nothing more than a greatly improved engine of the Newcomen type, much less wasteful of fuel, able to make faster strokes, but still only suitable for pumping, still single-acting, with steam admitted during the whole stroke, the piston, as before, pulling the beam by a chain working on a circular arc. The condenser was generally worked by injection, but Watt has left a model of a surface condenser made up of small tubes, in every essential respect like the condensers now used in marine engines.

Fig. 6 is an example of the Watt pumping-engine of this period. It should be noticed that, although the top of the cylinder is closed and steam has access to the upper side of the piston, this is done only to keep the cylinder and piston warm. The engine is still single-acting; the steam in the upper side merely plays the part which was played in Newcomen's engine by the atmosphere; and it is the lower end of the cylinder alone that is ever put in communication with the condenser. There are three valves,—the "steam" valve *a*, the "equilibrium" valve *b*, and the "exhaust" valve *c*. At the beginning of the drown-stroke, *c* is opened to produce a vacuum below the piston and *a* is opened to admit steam above it. At the end of the down-stroke *a*

and *c* are shut and *b* is opened. This puts the two sides in equilibrium, and allows the piston to be pulled up by the pump-rod P, which is heavy enough to serve as a counterpoise. C is the condenser, and A the air-pump, which discharges into the hot well H, whence the supply of the feed-pump F is drawn.

In a second patent (1781) Watt describes the "sun-and-planet" wheels and other methods of making the engine give continuous revolving motion to a shaft provided with a fly-wheel. He had invented the crank and connecting-rod for this purpose, but it had meanwhile been patented by one Pickard; and Watt, rather than make terms with Pickard, whom he regarded as a plagiarist of his own ideas, made use of his sun-and-planet motion until the patent on the crank expired. The reciprocating motion of earlier forms had served only for pumping; by this invention Watt opened up for the steam engine a thousand other channels of usefulness. The engine was still single-acting; the connecting-rod was attached to the far end of the beam, and that carried a counterpoise which served to raise the piston when steam was admitted below it.

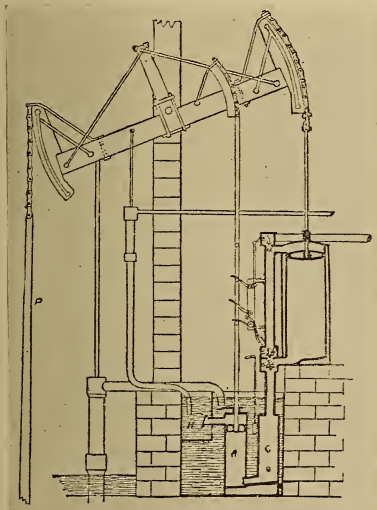


FIG. 6.—WATT'S SINGLE-ACTING ENGINE, 1769.

In 1782, Watt patented two further improvements of the first importance, both of which he had invented some years before. One was the use of double-action, that is to say, the application of steam and vacuum to each side of the piston alternately. The other (invented as early as 1769) was the use of steam expansively, in other words, the plan (now used in all engines that aim at economy of fuel) of stopping the admission of steam when the pison had made only a part of its stroke, and allowing the rest of the stroke to be performed by the expansion of the steam already in the cylinder. To let the piston push as well as pull the end of the beam Watt devised his so-called parallel motion, an arrangement of links connecting the piston-rod-head with the beam in such a way as to guide the rod to move in a very nearly straight line. He further added the throttle-valve, for regulating the rate of admission of steam, and the centrifugal governor, a double conical pendulum, which controlled the speed by acting on the throttle-valve. The stage of development reached at this time is illustrated by the engine of Fig. 7 (from Stuart's *History of the Steam Engine*), which shows the parallel motion *pp*, the governor *g*, the throttle-valve *t*, and a pair of steam and exhaust-valves at each end of the cylinder. Among other inventions of Watt were the "indicator," by which diagrams showing the relation of the steam pressure in the cylinder to the movement of the piston are automatically drawn; a steam tilt-hammer; and also a steam locomotive for ordinary roads,—but this invention was not prosecuted.

In partnership with Matthew Boulton, Watt carried on in Birmingham the manufacture and sale of his engines with the utmost success, and held the field against all rivals in spite of severe assaults on the validity of his patents. Notwithstanding his accurate knowledge of the advantage to be gained by using steam expansively, he continued to employ only low pressures—seldom more than 7 lbs. per square inch over that of the atmosphere. His boilers were fed, as Newcomen's had been, through

an open pipe, which rose high enough to let the column of water in it balance the pressure of the steam. He introduced the term "horse power" as a mode of rating engines, defining one-horse power as the rate at which work is done when 33,000 lbs. are raised one foot in one minute. This estimate was based on trials of the work done by horses; it is excessive as a statement of what an average horse can do, but Watt purposely made it so in order that his customers might have no reason to complain on this score.

In the fourth claim in Watt's first patent, the second sentence describes a

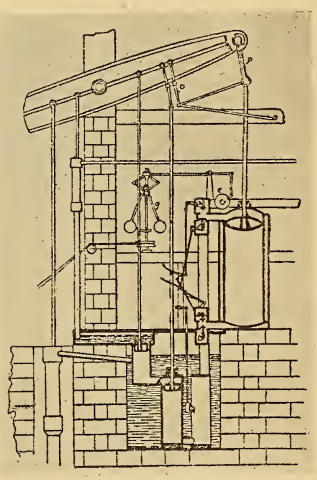


FIG. 7.—WATT'S DOUBLE-ACTING ENGINE, 1782.

non-condensing engine, which would have required steam of a higher pressure. This, however, was a line of invention which Watt did not follow up, perhaps because so early as 1725 a non-condensing engine had been described by Leupold in his *Theatrum Machinarum*. Leupold's proposed engine is shown in Fig. 8, which makes its action sufficiently clear. Watt's aversion to high-pressure steam was strong, and its influence on steam engine practice long survived the expiry of his patents. So much, indeed, was this the case that the terms "high-pressure" and "non-condensing" were for many years synonymous, in contradistinction to the "low-pressure" or condensing engines of Watt. This nomenclature no longer holds; in modern practice many condensing engines use as high pressures as non-condensing engines, and by doing so are able to take advantage of Watt's great invention of expansive working to a degree which was impossible in his own practice.

The introduction of the non-condensing and, at that time, relatively high-pressure engine was effected in England by Trevithick, and in America by Oliver Evans about 1800. Both Evans and Trevithick applied their engines to propel carriages on roads, and both used for boiler a cylindrical vessel with a cylindrical flue inside—the construction now known as the Cornish boiler. In partnership with Bull, Trevithick had previously made direct-acting pumping-engines, with an inverted cylinder set over and in line with the pump-rod, thus dispensing with the beam that had been a feature in all earlier forms. But in these "Bull" engines, as they were called, a condenser was used, or, rather, the steam was condensed by a jet of cold water in the exhaust-pipe, and Boulton and Watt successfully opposed them as infringing Watt's patents. To Trevithick belongs the distinguished honor of being the first to use a steam carriage on a railway; in 1804 he built a locomotive in the modern sense, to run on what had formerly been a horse tramway in Wales, and it is noteworthy that the exhaust steam was discharged into the funnel to force the furnace draught, a device which twenty-five years later, in the hands of George Stephenson, went far to make the locomotive what it is to-day. In this connection it may be added that as early as 1769 a steam carriage for roads had been built by Cugnot in France, who used a pair of single-acting high-pressure cylinders to turn a driving-axle step by step, by means of pawls and ratchet-wheels. To the initiative of Evans may be ascribed the early general use of high-pressure steam in the United States, a feature which for many years distinguished American from English practice.

Amongst the contemporaries of Watt one name deserves special mention. In 1781 Jonathan Hornblower constructed and patented what would now be called a compound engine, with two cylinders of different sizes. Steam was first admitted into the smaller cylinder, and then passed over into the larger, doing work against a piston in each. In Hornblower's engine the two cylinders were placed side by side, and both pistons worked on the same end of a beam overhead. This was an instance of the use of steam expansively, and as such was earlier than the patent, though not earlier than the invention of expansive working by Watt. Hornblower was crushed by the Birmingham firm for infringing their patent in the use of a separate condenser

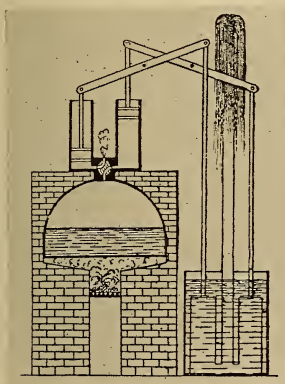


FIG. 8.—LEUPOLD'S NON-CONDENSING ENGINE, 1725.

and air-pump. The compound engine was revived in 1804 by Woolf, with whose name it is often associated. Using steam of fairly high pressure, and cutting off the supply before the end of the stroke in the small cylinder, Woolf expanded the steam to several times its original volume. Mechanically the double-cylinder compound engine has this advantage over an engine in which the same amount of expansion is performed in a single cylinder, that the sum of the forces exerted by the two pistons in the compound engine varies less throughout the action than the force exerted by the piston of the single-cylinder engine. This advantage may have been clear to Hornblower and Woolf, and to other early users of compound expansion. But another and probably a more important merit of the system lies in a fact of which neither they nor for many years their followers in the use of compound engines were aware,—the fact that by dividing the whole range of expansion into two parts the cylinders in which these are separately performed are subject to a reduced range of fluctuation in their temperature. This, as will be afterward pointed out, limits to a great extent a source of waste which is present in all steam engines, the waste which results from the heating and cooling of the metal by its alternate contact with hot and cooler steam. The system of compound expansion is now used in nearly all large engines that pretend to economy. Its introduction forms the only great improvement which the steam engine has undergone since the time of Watt; and we are able to recognize it as a very important step in the direction set forth in his "first principle," that the cylinder should be kept as hot as the steam that enters it.

Woolf introduced the compound engine somewhat widely about 1814 as a pumping-engine in the mines of Cornwall. But here it met a strong competitor in the high-pressure single-cylinder engine of Trevithick, which had the advantage of greater simplicity in construction. Woolf's engine fell into comparative disuse, and the single-cylinder type took a form which, under the name of the Cornish pumping-engine, was for many years famous for its great economy of fuel. In this engine the cylinder was set under one end of a beam, from the other end of which hung a heavy rod which operated a pump at the foot of the shaft. Steam was admitted above the piston for a short portion of the stroke, thereby raising the pump-rod, and was allowed to expand for the remainder. Then an equilibrium valve, connecting the space above and below the piston, as in Fig. 6, was opened, and the pump-rod descended, doing work in the pump and raising the engine piston. The large mass which had to be started and stopped at each stroke served by its inertia to counterbalance the unequal

pressure of the steam, for the ascending rods stored up energy of motion in the early part of the stroke, when the steam pressure was greatest, and gave out energy in the later part, when expansion had greatly lowered the pressure. The frequency of the stroke was controlled by a device called a cataract, consisting of a small plunger-pump, in which the plunger, raised at each stroke by the engine, was allowed to descend more or less slowly by the escape of fluid below it through an adjustable orifice, and its descent liberated catches which held the steam and exhaust-valves from opening. A similar device controlled the equilibrium-valve, and could be set to give a pause at the end of the piston's down-stroke, so that the pump-cylinder might have time to become completely filled. The Cornish engine is interesting as the earliest form which achieved an efficiency comparable with that of good modern engines. For many years monthly reports were published of the "duty" of these engines, the "duty" being the number of foot-pounds of work done per bushel, or (in some cases) per cwt. of coal. The average duty of engines in the Cornwall district rose from about 18 millions of foot pounds per cwt. of coal in 1813 to 68 millions in 1844, after which less effort seems to have been made to maintain a high efficiency. In individual cases much higher results were reported, as in the Fowey Consols engine, which in 1835 was stated to have a duty of 125 millions. This (to use a more modern mode of reckoning) is equivalent to the consumption of only a little more than 1¾ lbs. of coal per horse power per hour,—a result surpassed by very few engines in even the best recent practice. It is difficult to credit figures which, even in exceptional instances, place the Cornish engine of that period on a level with the most efficient modern engines—in which compound expansion and high pressure combine to make a much more perfect thermodynamic machine; and apart from this there is room to question the accuracy of the Cornish reports. They played, however, a useful part in the process of steam-engine development by directing attention to the question of efficiency, and by demonstrating the advantage to be gained by high pressure and expansive working, at a time when the theory of the steam engine had not yet taken shape.

The final revival of the compound engine did not occur until about the middle of the century, and then several agencies combined to effect it. In 1845, M'Naught introduced a plan of improving beam engines of the original Watt type, by adding a high-pressure cylinder whose piston acted on the beam between the center and the fly-wheel end. Steam of higher pressure than had formerly been used, after doing work in the new cylinder, passed into the old or low-pressure cylinder, where it was further expanded. Many engines whose power was proving insufficient for the extended machinery they had to drive, were "M'Naughted" in this way, and after conversion were found not only to yield more power, but to show a marked economy of fuel. The compound form was selected by Mr. Pole for the pumping-engines of Lambeth and other waterworks about 1850; in 1854, John Elder began to use it in marine engines; in 1857, Mr. Cowper added a steam-jacketed intermediate reservoir for steam between the high- and low-pressure cylinders, which made it unnecessary for the low-pressure piston to be just beginning when the other piston was just ending its stroke. As facilities increased for the use of high-pressure steam, compound expansion became more and more general, its advantage becoming more conspicuous with every increase in boiler pressure, until now there are few large land engines and scarcely any marine engines that do not employ it. In marine practice, where economy of fuel is a much more important factor in determining the design than it is on land, the principle of compound expansion has lately been greatly extended by the introduction of triple and even quadruple expansion engines, in which the steam is made to expand successively in three or four cylinders. Even in the building of locomotive engines, where other considerations are of more moment than the saving of coal, the system of compound expansion is beginning to find a place.

The growth of compound expansion

has been referred to at some length, because it forms the most distinctive improvement which the steam engine has undergone since the time of Watt. For the rest, the progress of the steam engine has consisted in its adaptation to particular uses, in the invention of features of mechanical detail, in the recognition and application of thermodynamical principles, and in improved methods of engineering construction, by which it has profited in common with all other machines. These have in particular made possible the use of steam of eight or ten times the pressure of that employed by Watt.

THE STRENGTH AND SAFE SPEED OF GRINDING WHEELS.

PROFESSOR R. H. SMITH contributes to *Industries*, August 15, and October 3, 1890, an elaborate mathematical investigation of the safe strength of emery-wheels, based upon the weight and tensile strength of a Bateman's emery-wheel. The specific weight of this wheel was 0.10645 pounds per cubic inch, and its breaking strength 1.143 pounds per square inch. The result of the calculation shows that the place of most dangerous stress is always a little nearer the center than the periphery of the wheel, the distance from the center varying from .43 to .47 of the radius. The maximum stress =

$$.245 \frac{w}{g} v^2,$$

or say one-quarter of the specific mass multiplied by the square of the peripheral velocity in inches per second. Applying this to emery-wheels, the maximum stress in pounds per square inch .0000675 multiplied by the square of peripheral speed in inches per second.

For sandstones the maximum stress = $.0000527\ v^2$. For an emery-wheel of the strength above given, 18 inches in diameter, the 1500 revolutions per minute maximum stress = 135 pounds per square inch, and the factor of safety $\frac{1143}{135} = 8.47$.

The "breaking speed" would be 4365 revolutions per minute, to allow for effects of vibration, sudden application of grinding-work, and for variation in tensile strength of material, which is said to fall occasionally to 700 pounds per square inch. Professor Smith considers a factor of safety of .6, or a stress of $\frac{1140}{6} = 90$ pounds per square inch, to be safe for a wheel that is carefully mounted and prudently used, without digging the work into the wheel. The corresponding safe speed, $\frac{4365}{\sqrt{6}} = 1780$ revolutions per minute. This corresponds to a linear speed of about 100,000 inches, or a little over 8000 feet per minute. A greater factor of safety should be taken for thin wheels than for thick ones, on account of their usually greater unsteadiness in running.

TRANSMISSION OF HEAT THROUGH BOILER PLATES.

THE rate of transmission of heat through the plates in a steam boiler per square foot of surface per hour and per degree of difference of temperature is not a constant quantity, but is a function of the temperature of the gases and of the water, of the thickness of the plate, of the condition of its surface as regards scale, soot, etc., and of the rapidity of circulation of the water and gas currents. Mr. Michael Longridge (*Industries*, January 31, 1890) gives the following empirical values, based upon experiments with Lancashire boilers, which he thinks may be adopted until further experience throws more light upon the subject:

M = number of heat units transmitted through the plates per square foot of surface per hour, and per degree of difference of temperature.

S = number of square feet of heating surface per pound of coal burned per hour.

	S=1.	1.5	2.	3.	4.
For very clean boilers	M=6.5	5.9	5.5	4.9	4.6
For fairly clean boilers	M=6.	5.4	5.1	4 6	4.3
For rather dirty boilers	M=5.5	4.9	4.6	4.2	4 1

STEAM ENGINE BREAKDOWNS.

By Prof. John E. Sweet, M.E.

SINCE the invention and building of steam engines there have been five items in cost attached to their running and maintenance: the interest on cost of machine itself with its protecting-house, the cost of steam, of oil, of engineer, and the cost of repairs, including the interruption of business whenever those repairs have to be made.

Should any old-timer be prepared with definite data, he could no doubt show without dispute that the number of breakdowns that occur to steam engine plants nowadays are enormously more frequent than of old, but whether, when all the circumstances are taken into account, to the credit or discredit of pioneers, is not very certain.

First, there are hundreds of engines to break, where there was one; the steam pressure used is multiplied from the seven pounds, in James Watt's time, to the one hundred and seventy-five pounds of to-day, and the increase of speed and pressure combined has changed the weight, and particularly the space occupied, at least from ten to one.

A fifty-horse power engine in the time of James Watt would occupy more room twice over than the dwelling of the engineer who ran it, while to-day a fifty-horse power engine could be hidden in the engineer's closet.

The entire journeys of the piston in the pumping engine at Smethwick, in England, which ran over a hundred years, would, if not stopped for an instant during that time, have made about 3650 million trips. There are hundreds of engines of that power running to-day that make as many turns in two and one-half years. If the breakdowns occurred only in proportion to the speed, for every year the high speed runs without repairs, the old engine would have to run forty, and if breakdowns only occurred in proportion to speed and pressure, the old engine would have had to run a thousand.

Bringing the comparison down to later times, when the slide-valve was standard, breakdowns and repairs, while less frequent than to-day, were not proportionately very much less, nor were the consequences proportionately less disastrous.

Owing to the slow speed and large clearance and self-relieving feature of the slide-valve, which would lift from its seat and allow the water to pass back into the chest, trouble from water was of little moment, and the breakdowns largely came from some parts breaking through weakness or by getting loose. More frequently than anything else, the follow bolts in piston would work out, fall in between the piston and cylinder-head, and sometimes knock out the head, and not unfrequently tear the frame in two between the cylinder and the pillow-block.

Nothwithstanding the admirable design, and in its early days the incomparable machine-work of the Corliss engine, it is doubtful if there has ever occurred any more costly breakdown in any engines of their size than has happened to this masterly machine. Comparing number with number, it is possible, in fact probable, that there has been a less percentage of breakdowns among engines of the Corliss type than the best of the later high-speed engines; but counting the cost in dollars and cents to the owner for repairs and delays, it is doubtful if the loss per horse power has been less.

When the breakdown does come to the large slow-speed engine, it is liable to be one that shuts down the works and is costly to repair.

By far the larger part of breakdowns in modern high-speed engines comes from water in the cylinder. This is hard to make engineers and owners believe, because they do not see why water should not come over as much in slow- as in high-speed engines. One reason is that the best of high-speed engines have marvelous, quick-acting governors. A heavy load thrown on will be responded to by the governors instantly, and a

sudden draught of steam has a tendency to lift the water, but it is not so much that the high speed is troubled worse with water as it is that it cannot get back into the steam-chest or out of the relief-valves quick enough, and, too, the high-speed short-stroke engines are very rigid, and so not only do not spring but bring up so suddenly that it is like the blow of a hammer rather than the pressure of a toggle-joint. While the frequency of the breakages are too prevalent and too evident, the absolute cost, except when they are general smash-ups, is not so serious, as duplicate parts and the small sizes to be handled usually make the delay comparatively small and often insignificant.

Were it not for the water question (which really is a question for the boiler-maker) with the present liberal proportions, efficient devices for preventing parts working loose and the excellent workmanship, it is safe to say the actual percentage of breakdowns of high-speed engines would not exceed the slow-speed, and the cost for repairs would be no greater and the delays greatly less.

How to make these breakdowns less frequent, less dangerous, less disastrous, and less expensive, has been no small part, and continues to be no small part, of the study of the engine builder.

Were it possible to build an engine requiring no attention, one that would not wear out or break down, and have the machine fairly economical, the builder would need no other advertising to secure sales for his product beyond what the reputation of the product would make for itself. But to begin with, the perfection of a piece of cast-iron is not determinable from its external appearence, neither are forgings of wrought-iron ; and concealed defects in steel and malleable castings, which are desirable to use sometimes, are even more liable to occur, which render them more uncertain than cast- and wrought-iron. Steel forgings which are almost absolutely free from concealed defects, such as air-holes or defective welds, possess a peculiarity that renders it an undesirable material for certain parts of engines. Even steel of very low carbon, with an elongation of fifteen per cent., will, after a time, when used for such bolts as those used in the end of connecting-rods of marine style, break as square off as a piece of cast-iron, and it is these uncertain features in the materials which the engine builders have to deal with, and is one unavoidable source of breakdowns. The strength of the different parts, or at least the strain on the different parts produced by the direct pressure of steam, is a matter that can be figured, though seldom is, because practice has developed proportion far beyond those necessary to meet direct strains, and yet none too great to meet occasional accidental ones. When it is necessary to meet accidental strains so much greater than the direct strains, to figure the direct ones is like one cat-hole for the cat and a smaller one for the kitten. Aside from the accidents from water and imperfect material, both more or less out of control of the engine builder, there is another,—the personal uncertainty of the man in charge.

If bearings or slides did not wear or rust ; lubrication automatic and never failed ; if pet cocks, valves, and throttle would always open and shut themselves at the right time, and dirt keep its own place,—there would be very little use for an attendant ; but as none of them do so, the attendant becomes a necessity and a factor of uncertainty inversely proportional to his skill, faithfulness, and reliability.

The engineer may by carelessness be the direct cause of a breakdown (dropping a monkey-wrench between cross-head and cylinder-head while the engine is in motion might give evidence), or he may be the indirect cause by negligence in allowing the crank-box to run too loose, so that the constant hammering breaks its fastenings. A neglect of proper care by the engineer at the right time often leads to trouble.

But, aside from all points outside the control of the builder, there are still many things possible, if one has the courage to adopt them, that will reduce the frequency of break-downs.

In case of water in the cylinder, it is the inertia of the fly-wheel that does the damage. In the case of nearly every engine built—that is, all where the crank itself or governor are not directly connected to the fly-wheel—this is cer-

tainly preventable. All that is necessary is to make the connection between the wheel and shaft a friction connection. The fly-wheel fitting a taper seat on the shaft, a taper of say two to three inches to the foot and forced on by a feathered washer and nut or cross-key serves the purpose, and the cost would not be a noticeable feature compared to the entire cost of the engine. The impossibility of throwing the fly-wheel out of truth by keying would be worth the cost, and when done it would only be necessary to adjust the friction to the legitimate work, so that in case of accidental resistance the fly-wheel would slide along leaving the balance of the engine at rest. There is nothing new about this except its application to engines. The writer saw this applied to large forging machines nearly thirty years ago, used it successfully in a forging machine, and knows of it having been used on compressing engines for some years. This would not do in places like rolling-mills, where the fly-wheels are much more a part of the roll-trains than the engine.

There are two other safety devices possible in places,—friction connections and breaking-pieces. Probably no one has the courage to make a connecting or valve-rod like a trombone, with friction enough for legitimate work and slip enough for safety ; but why ?

Either the Buckeye or Westinghouse Company were bold enough to make the engine's piston the breaking-piece, or the cylinder-head so as to knock out without other damage ; and such a move has this merit: if the occasion never came where it might be wanted, no harm would be done ; but if the occasion did come, the result would be less disastrous.

Still, man is a curious animal, and it has been said that the trouble was, that when the accident occurred it was the broken cylinder-head the proprietor could see instead of the protected machine. Friction safety devices have the merit over breaking-pieces of cheapness, as the accident costs nothing in breakage and only readjustment in delays and more judgment for readjusting, for the same man who would complain at the breaking-piece would complain in the slip-joint, and while he would have to accept the breaking-pieces in spite of himself, he could piece out the wrench-handle and neutralize the friction safety device entirely.

Whatever the engine builder may do, the engine must take either water or steam, whichever the boiler gives, and is subject to the care of the attendant.

Unfortunately for the proprietor and the attendant or engineer, the custom and practice is to cut the duties and responsibilities short at both ends. The engineer should possess the ability to determine the safety and condition of the plant he is called upon to run, and should be asked to examine and report upon it. If he discovers dangerous points, he should report upon them, and if he knows of safety devices that have been neglected and recommends their adoption, his advice should be heeded. If he finds a condenser attached, with no efficient check between that and the engine, and the case is one that demands one (and it generally is), then, if it is not put in, a breakdown can be predicted, and the engineer is saved from blame. If more intelligence and knowledge is demanded from engineers, the demand will be met, and if more heed be taken of their recommendations, less breakdowns and delays will have to be paid for.

"SPONGE" SILK FABRIC.

Owing to its wonderful absorbent qualities, "sponge" silk fabric, made from the short combings of silk, is highly commended for use by machinists, and is used in many large factories throughout the New England States for wiping up oil. One of the hemmed machine cloths thirteen inches square will take up nearly a quart of oil. After being used once, these cloths need not be thrown away like waste cotton, but the oil may be extracted and the cloth washed for future use. Another great advantage of this material is that it does not generate fire when wet with oil, while cotton is the cause of many disastrous fires.

METHODS OF REDUCING THE FIRE LOSS.

By C. H. J. Woodbury, Member A.S.M.E.

PART I.—CONSTRUCTION.

THE writer of these articles some time ago read a paper on the above topic before the American Society of Mechanical Engineers. It is from that paper that these articles have been prepared, the changes made being only such as the space and requirements for its publication in CASSIER'S MAGAZINE rendered necessary.

In its design a mill for any standard line of manufacture is not a building whose arrangement and proportions are fixed upon at the whim of the owner, but they must conform to certain conditions of dimensions, stability, light, and application of power to satisfy the requirements essential for producing the desired results at the lowest cost,—circumstances and conditions to which capital has been mercilessly starved by close competition and the encroachments due to growing socialistic tendencies. As methods of manufacture change, so mill construction must in like manner be altered to conform to the new conditions.

Whatever changes may be made in methods of construction, the question of the fire hazard continues to be represented by an annual charge which differs from the other fixed charges of interest in that its ratio is a variable one and is based upon the estimated annual chance of fire. The more efficient the manner in which such a building can be arranged to resist fire, by so much will the hazard represented by the insurance premium become less.

Although a great deal depends upon construction, this hazard can never be reduced to zero, as that would indicate that the mill was absolutely fireproof. A fireproof mill, both in name and reality, must not only be built of incombustible material, but must also be capable of resisting any fire of its contents without destructive effects upon the structure. Such a building would be a commercial impossibility, both in regard to prohibitive costs and also the hindrances to manufacturing involved by a method of construction which would bear comparison with the casemates of fortifications, and is therefore unsuited to the conditions essential for the advantageous operation of machinery. It is apparent that the name of fireproof mills never deceived anybody, for the owners keep them insured, and the insurance companies charge a rate in accordance with their estimate of the hazard.*

The destructive consequences attending fire in such buildings, whose iron and masonry construction is called fireproof, shows that some other form of construction is necessary to obtain the desired result of minimizing the annual cost of the maintenance of the invested capital, as represented by insurance, depreciation, interest, and taxation. There is little incentive for entering into unusual expenses in the construction of a manufacturing building for the purpose of increasing its resistance to fire, unless the additional interest on such increase in the investment is to be met by a corresponding reduction in the annual cost of the fire hazard. In addition to these questions involving the annual maintenance of the plant, the increase in the expense of the building above a certain point may prove poor management by locking up capital for too long a time, and may tend to prevent the improvements in arrangement and construction which are necessary for the most advantageous manufacturing.

The method of mill-building known as slow-burning construction combines the advantages of low initial cost and great resistance to destruction by fire, the final result being that the manufacturing process is housed at the minimum annual

*William A. Green, when chief engineer of the Boston Fire Department, in answer to an inquiry from an official at Berlin, asking for a list and description of the fire-proof buildings at Boston, wrote that the Beacon Hill Reservoir was the only fire-proof building in Boston, although they did not at times feel quite sure of it.

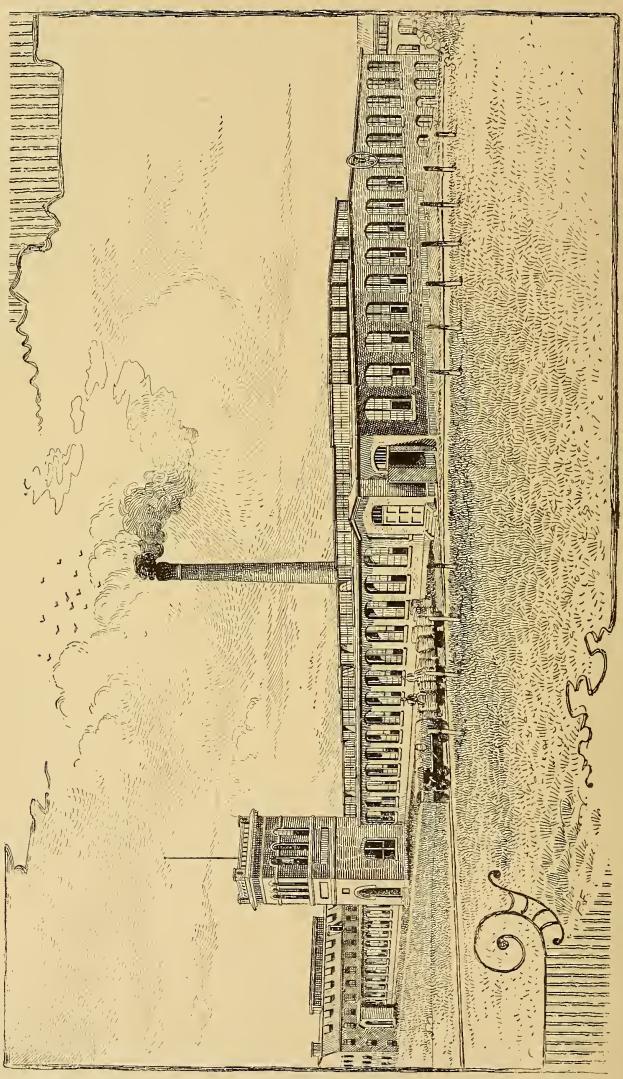


FIG. 1.—ONE-STORY MILL.

cost. Such slow-burning methods of construction also furnish the most advantageous arrangements for manufacture as to stability, light, and application of power; the whole being the result of the best fitness of means to ends in the effort to reduce the cost of production to its lowest terms.

The principal features of slow-burning construction may be illustrated by bits of experience drawn from many sources. The fundamental principle of such construction is to mass the material in such a way that there shall not be any concealed spaces about the structure, and that the number of projections of timber which are more easily ignited than the flat surfaces shall be reduced as far as possible; that iron portions of the structure shall not be exposed to the heat of any fire in the contents of the building, and furthermore that the isolation of the various portions shall be as complete as is feasible—both as respects one building to another and the various rooms and stories of the same building to each other.

It is a rare occurrence that one has an opportunity to arrange an establishment on an extended scale from the very beginning. In such instances it is easy to organize the whole so that the dangerous processes shall be relegated to special buildings, that the storage shall be separated from manufacture, that the progress of stock in process of manufacture shall be continuous, that due preparation shall be made for future extensions—and particularly in regard to the arrangement of building to grade—and that full arrangements for the application of power may be made so as to take advantage of the various possible economies from the latest state of the art. Under such circumstances the arrangement of all pipes and fire apparatus can be made to the most efficient purpose.

Far more engineering skill is required for the reconstruction of old establishments, bringing their methods as far as possible to the present state of the art; and in many instances this work has been done with but little interference with the production.

Some of the more salient features of modern mill construction pertaining to questions of resistance to fire can be briefly related, without entering upon the general subject of mill construction. The most important feature is that of the mill floors, which should be laid on beams, generally of Southern pine, 12 x 14 inches, or two inches larger when required by unusual loads or longer span than 22 feet (Fig. 2). These beams are placed from 8 to 10 feet apart between centers, and it is preferable that they should be made up of two pieces bolted side by side, with small blocks interposed to provide an air space of about an inch, as this will diminish the tendency to decay or to twist as the result of long-continued seasoning. At the anchorage of the walls the beams should rest upon cast-iron plates secured into the walls and provided with a rib on the top one and a half inches in height projecting into a wide groove across the bottom of the beam and brought to a firm bearing by a pair of wedges driven into a groove each side of the iron tongue. It is important that an air space should be left in the wall each side and at the end of the beam to prevent dry rot, and that the bricks in the wall for about four rows immediately above the beam should be laid in dry sand. A preferable modification of this is to use a cast-iron box made to receive the end of the beam and separated from contact on the top, end, and sides of the beam by ribs projecting on the inside of the box. As in the former case, these iron supports are securely built in the wall. This arrangement is much more stable in anchoring the beams to the wall, and if by reason of fire the beams break, they will slide out from their anchorages without injury to the wall as soon as the groove on the bottom of the beam clears the rib in the supporting plate.

At the columns beams rest on cast-iron caps which should present a supporting area at least three times that of the cross-section of the wood columns used, as the resistance of timber to longitudinal crushing is three times that of its resistance across the grain. The support from one column to the next should be made by cast-iron pintles, preferably those whose section is in the form of a Greek cross, as that presents advantages in the way of securely joining them to the timber beams. At the top of the pintle a cast-iron plate should support the base of the

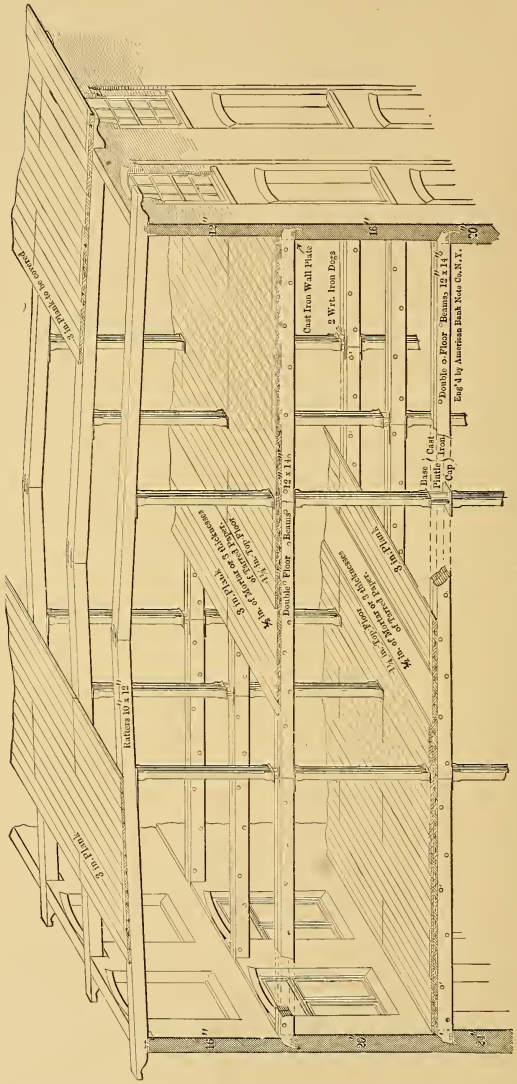


FIG. 2.—SLOW-BURNING CONSTRUCTION.

NOTE.—The figures on the right hand wall indicate the thickness at the panels in line with the windows, and not the thickness of the pilasters.

column above. A flat plate with a projection in the middle securing the column by insertion into the core of the column is preferable to the cup form which is so frequently used, as the latter tends to retain moisture to the deterioration of the column by dry rot.

Timber columns are preferred to those of iron, unless the load is greater than can be sustained by timber,—the limitation of a safe load on oak or Southern pine of straight grain and free from knots being about six hundred pounds to the square inch. Such columns, when subjected to destructive tests, give way by direct crushing, and for this reason the tendency of late years has been to make square instead of round colums. These offer no greater obstruction to the floor than the round columns and give about one-fourth extra resistance. Wood columns should have a 1¾ inch hole bored along the axis, and two ½ inch holes through the column near to each end, to diminish checking. Whenever the amount of load renders it necessary to use iron colums, they should be protected by wire lath and plaster, or by some of the special tiles made for the purpose.

The floor planks for this type of floor are generally made of spruce plank from three to four inches in thickness grooved on both edges and joined together by hard wood splines. These floor planks should be two bays in length, breaking joints at least every four feet.

Above this the top floor, of 1¼ or 1½ inch hard wood, is laid ; and in some instances the resistance of the floor to fire is greatly increased by laying a coat of plaster on the floor plank before the top flooring is put on. But the general method of increasing the resistance of the floor to fire is to cover the floor and beams on the under side with plaster laid on wire lathing. Whenever anything of this kind is done care should be taken that the covering to the timber should not be hermetically sealed, as that course increases the tendency to dry rot, particularly if the timber is not very thoroughly seasoned at the time of its application. There have been a number of failures of the strength of such construction on account of the disregard of this well-known principle : that it is not desirable to seal up the outside of unseasoned timber. This not only applies to the method cited above, but also to paints and varnishes which are laid on such work before it is thoroughly seasoned.

In mill floors of very large area care should be taken that the transverse shrinking of the floor should not pull the walls ; and on large low structures which are far enough across to be affected by a very slight longitudinal shrinkage of the beams, other methods of anchorage than the one referred to should be adopted.

The mill roof is similar to the floor in many of its characteristics, the timbers being somewhat lighter. If the roof is higher in the middle, the beams extend through the wall, and their ends properly cut serve as brackets for the roof planks, which are continued to the ends of the beams, and thus make a finish without calling for the construction of hollow cornices with gutters.

There will be no trouble from condensation on such a roof in cold weather if the plank and roof boarding are three inches in thickness, unless some wet process be carried on which produces a large amount of vapor, like paper manufacturing ; in this case it is advisable to make the roof four inches in thickness, also placing roofing felt between the plank and the roof boarding.

If it is desired to add finish by placing sheathing against the under side of the roof plank, such finish should be blind nailed, as the nails are good conductors of heat, and reaching to the colder portion of the roof, the moisture in the air will condense on the nail heads if exposed. It was formerly assumed that a double, sloping, hollow roof was necessary over a paper machine, but the above type of roof has been successfully employed for such purposes.

A coal tar concrete walk about the building will protect the foundations and also take care of water dripping from the roof. Under some circumstances the slope of the roof is reversed, being depressed at the middle and highest at the edges, the storm water being removed through gutters extending down through the middle of the building. This enables the walls to be extended above the roof, forming a parapet which is a great defence against fire from exposure outside,

and is a method of construction which is being generally followed in cities.

There is but little to be offered in this connection on the subject of walls; but the method of building pilastered walls is becoming more frequent, as it affords an opportunity to dispose the brickwork more rigidly than in plain brick walls, and also to introduce features of architectural symmetry. With buildings one or two stories in height, walls are made of plank in a manner similar to the mill floor, producing at low cost a building which is strong, warm, and light, without also containing the combustible features of an ordinary frame building.

Such a mill floor and columns, while possessing in a very high degree features which offer resistance to fire, and are weakened only to a slight extent as they are slowly burned away under exposure to a very severe fire, also possess the merit of great economy, both as regards the low price of construction, and in that the floor is thinner in comparison with joisted floors of equal strength, saving in this respect for every floor in a building about ten inches in height of wall, stairs, belting, steam pipes, and all vertical connections reaching from floor to floor—a saving which amounts to considerable in the total cost of building.

It is important, however, that floors should not be pierced with unprotected openings for stairways, elevators, or main belts. There is no record of such a mill floor, without belt or other holes in it, being burned through by a fire starting in the room below.

The principles of mechanics to be followed in the design of a mill floor are not those of the ultimate resistance to breaking, but of the amount of distortion which it will be permissible to impose upon the machinery by reason of the yielding of the floor. The usual method of fixing upon the limit of such deflections as a constant ratio of the span is clearly wrong in principle, the form of the flexure being a curve, and, therefore, not a constant ratio of the span. The proper allowance, however, of the measure of the amount of distortion allowed to the floor is that of the mean radius of curvature—a safe limit being that the deflection in inches should not exceed .0012 multiplied by the square of the span in feet; the desired result is to fix upon conditions of stiffness of the floor plank and the floor beams, which will cause it to deflect to an equal radius of curvature in both directions by the same load per square foot.

Floors near the earth in basements should be well ventilated, if there is a space between the floor and the surface of the earth; but, unless that space is continuous and two or three feet in height, it is better to lay the floor directly upon the earth, taking care to prevent dampness by putting in a layer of stones or cinders. Above this the sills for the floor are laid in a trench with coal-tar concrete, which is also laid between the sills, on a level with the top of them, and the floor boards are laid over this. When well-seasoned chestnut is used for this purpose, it will last a great many years without dry rot. Cement concrete will cause timber to decay rapidly. The sills are not necessary except to furnish material to secure lag screws holding down quick-running machinery; and where the two courses of floor plank are sufficient for such purposes, the sills may be omitted and the plank laid directly upon the concrete.

Windows for a mill should be placed as high as possible, as the illumination from the upper part of a room is much more uniformly diffused. The window-sills should be sloping, in order that articles should not be left on them in a disorderly manner. The architectural effect is usually heightened by placing sashes as near to the line of the inside of the wall as possible, making the disclosure or opening around the sash on the outside as large as possible. Ventilation can generally be arranged more satisfactorily by means of stationary sashes, the upper part of which swings like a transom over a door. In places where the work will be disturbed by currents of air, a desirable form of window ventilator is made by deflecting a portion of the middle of the sash—about eighteen inches in height and of same width—inward into the room, covering the top of the bracket-like projection thus formed with a cover which can be opened at will. The air from the outside is directed upward toward the ceiling, thus giving a uniform circulation in the room without causing

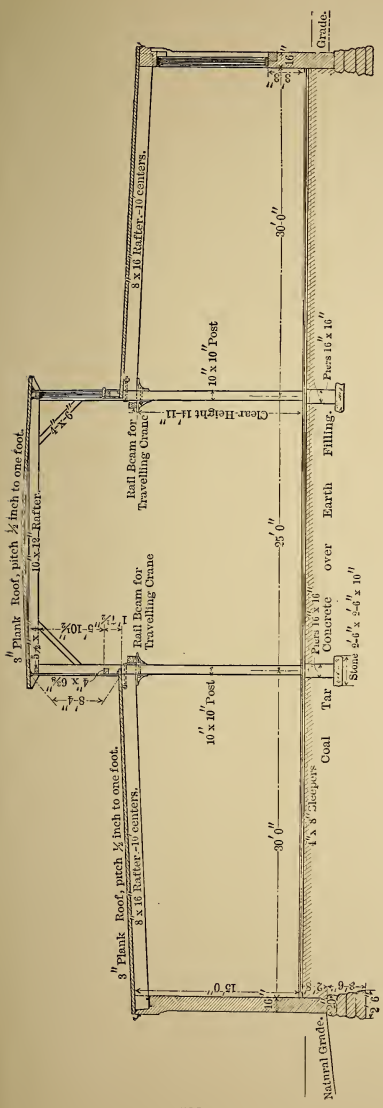


FIG. 3.

rapid currents. In case the windows admit too much light, this can be readily modified by painting the inside of the windows with a mixture of turpentine with zinc white. The amount of obstruction desired can be readily fixed upon after a few trials.

In one-story mills, and in the upper stories of wide mills, it is necessary to introduce light through the roof. While the expensive English ridge and furrow roof gives a very soft and blended light, it is hardly adapted to the northern part of the United States, on account of the difficulties with snow, and monitor roofs or hipped skylights give the best satis-

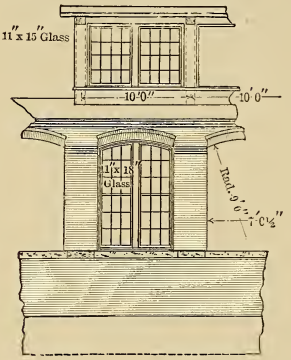


FIG. 4.

faction. If the latter are used, it is desirable in many instances that the lower part of the space under the skylight be separated from the room below by means of glazed sashes, placed flush with the ceiling. The monitor roof of a one-story machine shop affords an opportunity for a traveling crane with a minimum of building space (Figs. 3 and 4).

Stairways should not be placed in direct communication between different stories of the mill, but in masonry towers, with substantial doors at each story. Although almost generally a better architectural effect can be produced by building such stairway towers on the outside of the mill, yet in many instances principles of economy can best be served by building the tower inside of the mill at a corner. Stairways should be made in straight runs, with square turns rather than spirally. Foothold on the stairway

may be increased either by laying upper treads containing a number of grooves, similar to those frequently used on the steps and platforms of street cars, or, what is better, by using the silicate grooved tiles made especially for the purpose and extensively used in England.

Elevators should be so arranged that they would not serve as a flue under any circumstances; but it is not necessary to place them in a tower outside of the building, as elevators through any portions of mills can be safely placed at almost any point desired for sake of convenience, and the openings kept closed by means of automatic hatches.

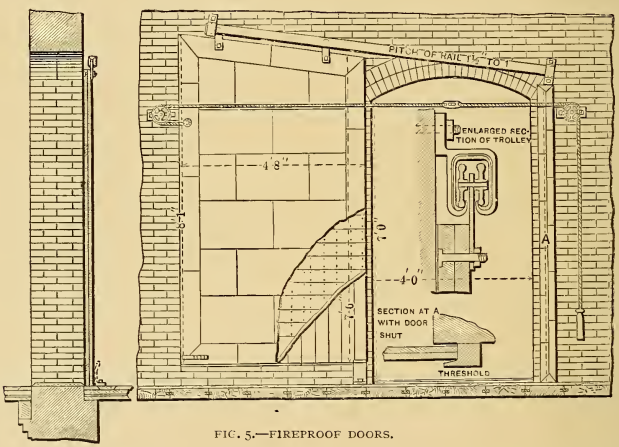


FIG. 5.—FIREPROOF DOORS.

The division of mills into various portions by means of fire-walls is frequently not so efficient as assumed, by reason of the lack of fire-doors to fulfill satisfactorily the purpose of resisting fire. The best form of fire-door is that made of two thicknesses of matched boards, placed at right angles to each other and nailed together, being covered on the outside by tin, securely locked together and held to the door by numerous hanging strips (Fig. 5). The door should be secured to the hangers by means of bolts, and not screws, and the rail upon which it runs should be strongly bolted to the wall. When closed, such door should fit into a jamb and be securely held in this manner against the wall. Such doors are frequently hung upon an inclined track, and, by some application of highly fusible solder at the catch, are so arranged that they will be closed by the heat of a fire, if not closed by hand. This same principle may be applied to fire-proof shutters hung over various openings which necessarily exist in walls which are desired to form a fireproof separation between various portions of a building. A fire-wall must extend through the roof, cutting off continuity of woodwork, especially at the roof cornices. The top of such a fire-wall can be covered with tiling, which is made in special form for such purposes, better than by a stone coping.

In this treatment of the arrangement of buildings to resist fire consideration has not been given to the cost of land, which is of itself an important factor in determining what arrangements will be the most expedient for an establishment. Where land is expensive, or where there are limitations in the space suitable for building, it is frequently necessary to build mills and shops higher than would be preferred under other conditions; but where circumstances will permit it, the one-story mill has been very successful, not merely in immunity from fire and

very low cost per square foot of floor, but also in the advantages of manufacturing, particularly in regard to cost of supervision and movement of the stock in process of manufacture. These are questions which must be determined, not merely in regard to the various processes of manufacture, but the individual needs of each concern; the position of the fire risk in the matter being that the hazard of a building increases very rapidly with its height and to some extent with its area. The extension of one-story buildings over too large an area will not be commended, and certainly, as regards the question of fire, it has a tendency to place too large a property in direct exposure to a very wide hazard.

The illustration (Fig. 1) is taken from a photograph of a one-story cordage factory designed by Stephen Greene, Member of the American Society of Mechanical Engineers. This mill was erected in place of a three-story building like the one shown in the background of the picture, which had been destroyed by fire, but the cost of manufacture was so much less in the new mill than in the old mill that the latter could not compete with it; and, having outlived its usefulness, was taken down as a cumberer of the ground in order to afford an opportunity for the extension of the one-story mill.

Some textile mills have been built in the form of the block letter U, this form having been decided upon as giving the conditions of lowest resultant cost. One wing, two stories in height, contains weaving; the other wing, three stories in height, contains carding and spinning; while the engine is placed in the connecting building. The pickers and boilers are in outside buildings, so placed that they will not interfere with future extensions of the building into the form of the block letter **H**.

In this connection there is but little reference to be made to storehouses, except to mention the necessity of the closest supervision of their contents. The preferable arrangement of stairways and elevators for such structures of more than one story in height is to place them in towers upon the outside of the building, not directly connected to the rooms, but reached by means of open galleries which lead from the door of the storehouse to a corresponding door in the tower at the same level. The height of each story should be low enough to prevent overloading. The best conditions of safety require that not over one row of stock in bales on end should be placed on a floor. It is very important that the floors of storehouses should be made as tight as possible and provided with scuppers with swinging covers on the outside to discharge any excess of water thrown on them in case of fire.

NEW VERTICAL ENGINE.

THE new triple-expansion engine, of which we show illustrations on another page of front and end, has been recently brought out by the English firm of Ernest Scott & Co., Newcastle-on-Tyne, and is unlike any engine built in America. It was designed to obtain extreme steadiness in running, as well as economy, and the same type of engine has proved very successful for marine practice, which requires heavy and continuous running. The size of the cylinders of the engine illustrated are H. P., 20 inch; I. P., 33½, and L. P., 53½. The stroke is 36 inches, and it makes 70 revolutions per minute. The nominal horse power it will develop is 960, but the manufacturers think that the most economic load is about 800 horse power. The steam used is at 150 to 160 pounds. Its three cranks are at an angle of 120° to each other. A number of new vertical engines have recently been brought out by leading American builders which have many features commending them for economy and close regulation. Among the manufacturers are Armington & Sims, The Ball & Wood Company, and The Lake Erie Engineering Works. The Ball Engine Company, of Erie, Pa., has a triple-expansion engine of vertical type in successful operation in Rochester, N. Y., where it supplies the power for the dynamos for the Rochester Railway Company.

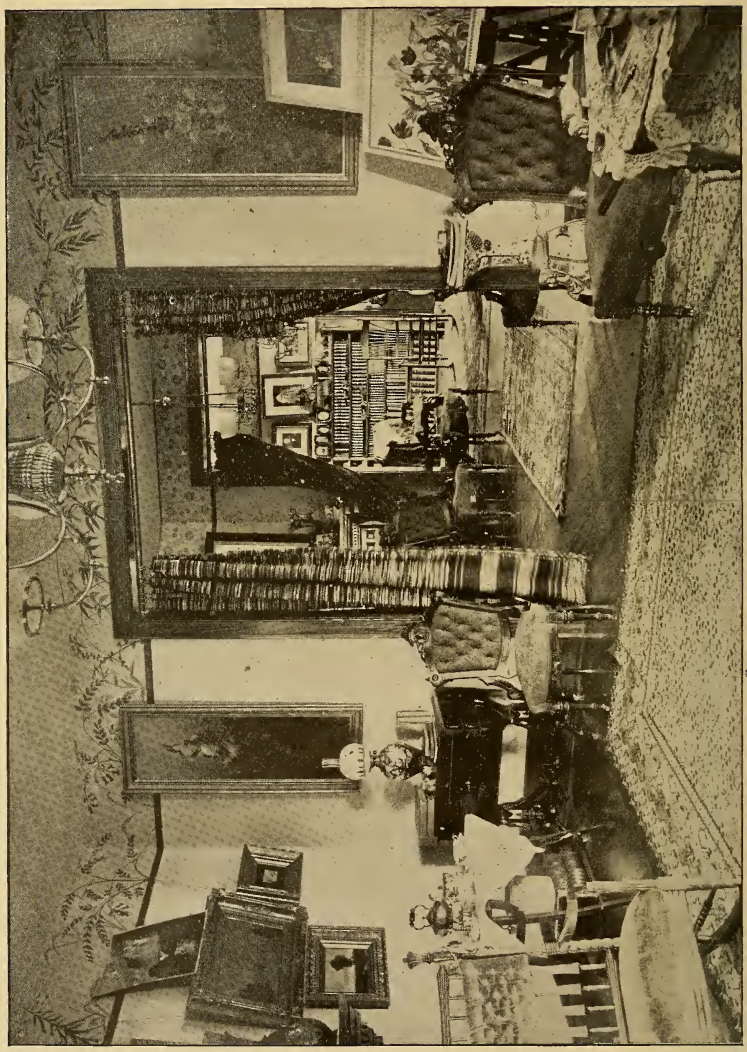


Robert H. Thurston

ROBERT H. THURSTON.

THE advances which have been made during the past quarter of a century in engineering as a learned profession have led to the formation of a class of engineers of the highest rank who have achieved fame not by the building of great structures or the making of great inventions, but by becoming leaders in theoretical and scientific research, in the organization of schools of engineering, in the education of the engineers of the future, both by teaching and lecturing in such schools, and by authorship. In all ages and in all professions as high and as lasting honors have been given to the leaders of thought as to those who have made material monuments, conquered nations, or amassed wealth. It is of one of these leaders the writer would say a few words.

The name of Robert H. Thurston, director and reorganizer of Sibley College, Cornell University, will forever be cherished by all who are interested in mechanical engineering as one whose entire life has been solely devoted to the welfare of that noble profession with which he has always so closely identified himself. Mr. Thurston was born at Providence, R. I., in 1839. His father was the Robert L. Thurston who founded the Providence Steam Company in 1837. He received his early education at Brown University, whence he graduated in 1859, when he was taken into the firm of Thurston, Gardner & Co. as salesman. Previous to this time, however, and while pursuing his studies at the university, he applied himself assiduously to the practical work of mechanical engineering, working in his father's shops successively as pattern-maker, draughtsman, moulder, and machinist, so that he had acquired a practical knowledge of the business calculated to serve as a good foundation for his many researches and discoveries in the vast field of mechanical engineering. After he had been two years with the firm the war broke out, and, like many more of his countrymen, he was anxious to get to the front. With this end in view he applied to the Navy Department early in 1861 for an appointment as assistant engineer. In the summer of the same year he passed the necessary qualifying examination and was attached to the war-ship *Unadilla* as senior assistant. Previous to reporting for duty in his new vocation, he completed some designs of his own which he had previously been working on for the Sickles and Greene engines in his father's workshops. From the time of his receiving appointment to the *Unadilla* to the year 1866 Mr. Thurston served successively on the *Princess Royal*—a captured blockade runner—and the United States war-vessels *Chippewa*, *Maumee*, *Pontoosuc*, and the greatest monitor ironclad, the *Dictator*. During his varied experience on board these vessels Mr. Thurston was not slow to take advantage of the exceptional opportunities afforded him for making practical observations of the many exigencies that attend the working and managing of such engines as those of which he had charge, and the best means of improving and perfecting the same, while he also found leisure to continue the pursuit of his professional studies. When the war ended he received a commission as a first-class engineer, and was appointed acting assistant professor in the department of natural and experimental philosophy at Annapolis, under Dr. A. W. Smith, who died very suddenly a few weeks after this appointment, leaving Mr. Thurston in full charge of the department. This position he held for several years. He resigned his commission in the navy in 1871, to take effect in 1872, after being offered, in 1871, an appointment in the newly-founded Stevens Institute of Technology, at Hoboken, that of professor of mechanical engineering, a position he occupied until 1885, the year in which he assumed charge of Sibley College. During these fourteen years, while he was engaged in teaching some hundreds of mechanical engineering students who are now in active practice, he found time to do a great deal of other valuable professional work. He organized a mechanical laboratory



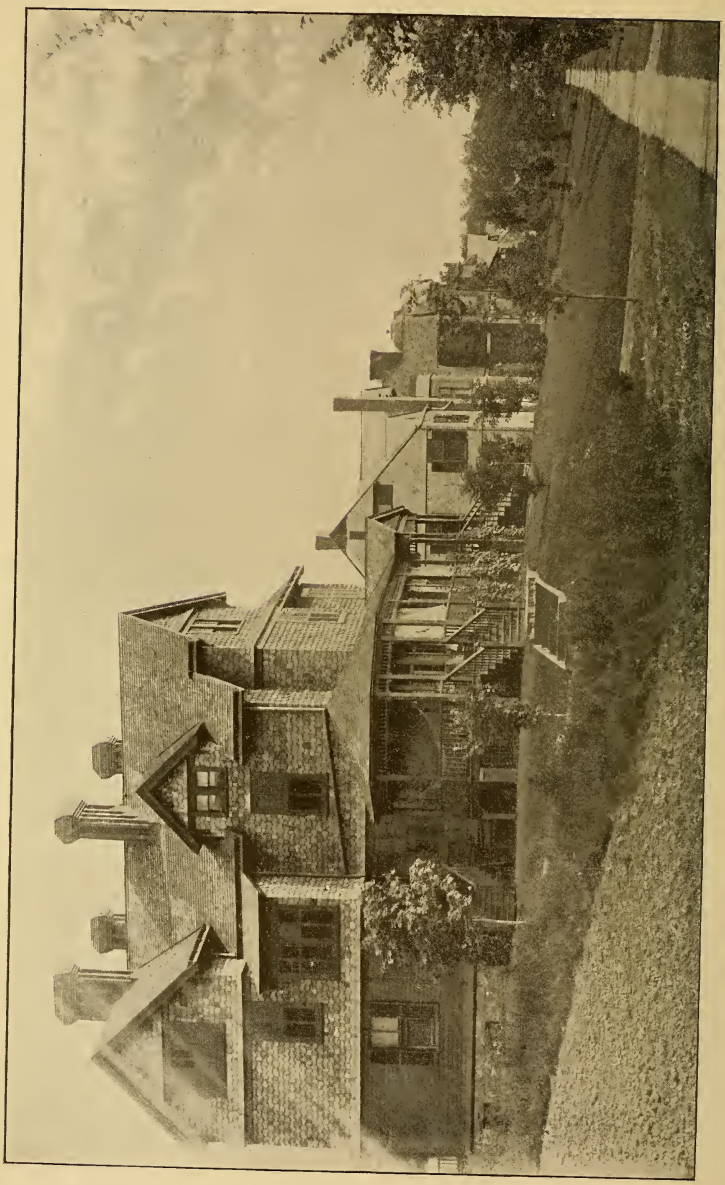
DRAWING-ROOM IN RESIDENCE OF ROBERT H. THURSTON.

of research at the Stevens Institute, in the investigation of such problems as frequently came under his own observation and that of his colleagues. He was a leading member of the United States Board appointed in 1875 to test steel and iron, directing part of the work completed by that board, and investigating the laws of friction and the properties of alloys of copper, zinc, and tin, a research which resulted in the determination of the relative values of those elements. Among the many other honorary positions filled so creditably by this able engineer are: member of the United States Board to ascertain the causes of steam boiler explosions, member of the Scientific Commission of the United States to the Internation Exhibition at Vienna, and as a member of the international jury he assisted in securing recognition of our claims to superiority in some departments of machine construction. Prior to the year 1882 Sibley College had been the mechanical department of Cornell University, which, in accordance with the United States land grant act, the State of New York and Mr. Cornell were to found, in order that the institution might pursue, as its leading object, the promotion of the useful arts. The demand for technical education, however, having vindicated the wisdom of forming a real engineering college, in charge of "a director," with instructions to plan the system, lay out proper courses of study, and to suggest desirable changes in methods of instruction, buildings, equipments, and whatever else would seem desirable, it was proposed to thoroughly reorganize the institution, Mr. Thurston being asked to accept the position of director.

After due deliberation on the responsibilities of such a position and the splendid possibilities of the proposition, Mr. Thurston resigned his position at the Stevens Institute, assuming charge of Sibley College, reorganizing it, readjusting the older departments, and creating a department of mechanical engineering, which has since become a most important branch of study at Cornell. The professor had many difficulties to overcome in this great undertaking, but it is needless to say how well he succeeded at last in establishing the work he had undertaken. The growth of the enterprise since 1885 has been remarkable, as have been the results each successive year. The number of students who graduated in 1886 was 5; the next year 16 took first degree of Master in Mechanical Engineering, and 3 more the higher degree. The third year, 1888, 19 took the first degree, and 6 the higher one. In 1889 27 took first, and in 1890 54 took the degree of Mechanical Engineer, and 6 that of Master, the latter including a number of distinguished professors and instructors from other colleges. During this period the number of students increased rapidly up to the present time. There are now over 500 students in the college.

The result of this training in mechanical engineering is, that the authorities have been compelled to consider the immediate enlargement of the buildings and equipments and the teaching force. In the term just commenced steps are being taken to greatly increase the accommodations to meet the ever-increasing demand from intending pupils. Thus it can be easily surmised that Mr. Thurston is kept very busy. At present his attention is partially occupied in superintending the erection, at the college, of several thousands of dollars' worth of new machinery, an electric-lighting apparatus, the putting down of underground cables, and many other forms of apparatus that have been found necessary to have in the college. He has just finished his "Life of Fulton," and the second part of his "Manual of the Steam Engine" is now in the hands of the printers.

He was the first president of the American Society of Mechanical Engineers, has been for many years member of the American, French, Scotch, Austrian, and German Societies of Civil Engineers, the American Society of Mining Engineers, the British Institution of Naval Architects, the British and American Societies for the Advancement of Science,—three times vice-president of the latter,—member of the Loyal Legion, *Officer de L' Institution Publique de France*, and was given the degree of LL.D. by his *alma mater*, Brown University, on the thirtieth anniversary of his graduation, and the honorary degree of Doctor



RESIDENCE OF ROBERT H. THURSTON, ON THE CAMPUS, AT ITHACA, N. Y.

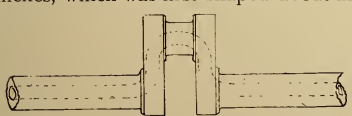
of Engineering by Stevens University when he left in 1885.

Mr. Thurston has written many works on topics relating to steam engineering, and, as has already been said, is at present employed, in addition to his other numerous occupations, in writing the second part of his "Manual of the Steam Engine." Among other works from the pen of this noted engineer are: "History of the Growth of the Steam Engine," "A Manual of Steam Boilers: their Design, Construction, and Operation," "Materials of Construction," "Stationary Steam Engines," "Conversion Tables," "Handbook of Engine and Boiler Trials," "Heat as a Form of Energy," "Steam Boiler Explosions: Theory and Practice," "Manual of the Steam Engine," a three-volume treatise on "The Materials of Engineering," and "Friction and Lost Work." He has also written some two hundred and fifty valuable papers on various engineering topics which are highly prized by the profession, and edited the reports of the commissioners of the International Exposition at Vienna, 1873. He has contributed to Appleton's Cyclopedia a biographical sketch of Professor William J. M. Rankine, papers on "The Design of Roofs," on "Steam Engine," "Steam and Steam Boilers," "Steam Carriage," "Steam Locomotive," "Steam Navigation," "Strength of Materials," and to Johnson's New Universal Cyclopedia articles on "Crushing- and Grinding-Machinery," "Friction," "Governors," "Lathes," and "Lubricators." He contributed largely to the Century Dictionary.

During the thirty-three years of his professional career, Mr. Thurston has followed a system of professional practice of a very extensive character, and has always intended to make the practice of his profession his exclusive vocation. In this determination he has been somewhat withheld in his desire to be of service to the profession in the inauguration of schools of engineering and the promotion of the mechanical engineer to a scientific foothold.

ENGINE SHAFTS WITH A STEEL CORE.

THE difficulty and expense sometimes necessary to make perfect shafts for center-crank engines have led to a series of experiments by the Burton Machine Company, of Erie, Pa., which may be of interest to engine manufacturers. They have recently made some shafts which are a combination of steel and cast-iron. For a shaft which when finished was to be three inches in diameter they used a core which consisted of a steel rod of one and a half inches, which was first shaped about as



CAST-IRON SHAFT WITH STEEL CORE.

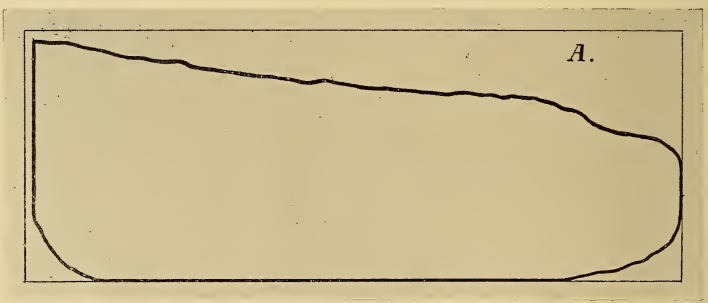
seen in the dotted lines in the engraving below. Around this was poured a casting of iron to which had been added from 15 to 20 per cent. of steel turnings. It is claimed that a perfect welding of the two metals resulted. The engraving shows a plain crank, but shafts with counterbalances or full discs may be cast in the same manner. These shafts are finished complete from the shaft centers and are not set off to turn the pin, as is the usual practice, which should insure perfect alignment of the shaft and pin, making it possible to finish shafts having full discs or counterbalances as readily as a plain shaft. It is claimed that these shafts would show greater stiffness and better wearing qualities than can be obtained in forgings, as well as being much cheaper. If, as it is claimed, a perfect weld is obtained, the idea of using the steel core seems to be an excellent one. Some engine manufacturers no longer use anything for their shaft except cast-iron, which, if made sufficiently heavy, proves as satisfactory as a forging, and of course much cheaper to make.

STEAM POWER AND THE COAL BILL.

By Thomas Pray, Jr.



THE coal bill as allied to the steam power is to the owner one of the continual reminders of a call on the pocket-book, and may be classed, as a rule, on a par with the landlord's call for rent, or the tax collector's annual, or other invitation to write out a check, and the one is as pleasantly received as the other in a majority of cases. Coal as a chemical compound is well known, and to most business men who use it for their power for any purpose it is not a small matter in the expense account of each day or year.



TAKEN FROM AN ORDINARY LINK-MOTION ENGINE.

In a technical way a lump of coal has a given number of atoms of CHO as it may be anthracite, bituminous, or semi-bituminous, and the theorist has an exceedingly plausible way of explaining how many cubic feet of air are required to consume with propriety and economy the various latent gases confined in a lump of coal "black diamonds" to become *sensible* and *efficient* when heated in the furnace and properly mingled with the atmospheric air, the resultant compound being incandescent gases of a high temperature, now harnessed on their way to make water hot and in turn to add increments of heat successively to the water so that it shall break away in its progression to a greater volume of less density and become available as the "moving power of all the higher civilization," steam.

Coal and carbon are synonymous terms, and the coal is carbon in the impure state, its impurities being varied according to the locality, and also varying in turn the character of the product, or changing the name of the coal. Anthracite coal has in its composition the highest amount of carbon, and the bituminous coal comes next to it in quality, or of its proportion of carbon. The composition of anthracite coal makes it nearer smokeless than others; the bituminous has more hydrogen than the anthracite and makes more smoke, the percentage of carbon in different coals varying from 68 to 91 per cent.

Of hydrogen, anthracite coals carry a small percentage, 2¾ to 4½; the Welsh and Australian somewhat higher than our own, and the oxygen is mixed sometimes more and sometimes less with nitrogen, sulphur, etc. As a rule, the coal having highest carbon has lowest H or O, the O and mixtures amounting in some coals to 20 or 25 per cent., making the coal less valuable as the percentage of O and inferior mixtures are higher in amount.

Incidentally it may interest the reader to know that carbon is the predominant element of the majority of substances known to us, no other one element existing in the same number of substances or in the same amount, when considered in a chemical sense.

But the business man as a rule does not stop to study the chemistry of coal combustion and evaporation. He does not care to look into specific and latent heat. He don't care whether heat is sensible or otherwise, so long as his pocketbook escapes severe scorching, and as to whether he is or is not interested in thermo-dynamic theories or in the abstract questions of the day as to the evaporative power of "our" boiler which soars over all others 16.3482 per cent. or some other decimal that would distort the jaw if not the eardrum. He does not recall the precise factor of superheating required to exploit "our" accessory, nor does he wish some of the many proffered improvements, all of which cost a good amount of cash and seem to him problematical as to returns in dollars and cents to him in saving.

Here, then, is the "divide" between the theory and practice in steam using. Theory bases upon certain known quantities (which are few in comparison) a relation with many others that are unknown, except as settled in each case, and under each train of circumstances, and these are constantly varying,—a result that may or ought to affect the final cost of a H. P. and to be of advantage to the purchaser.

Practice, that is usually long-headed and counts the cost before embarking, looks at it and judges somewhat from experience, and asks what results are to be guaranteed, and is met with a confused and indefinite lot of amounts and quantities so connected that he can make nothing out of them in his short-cut way, and he can see at once that any result based on such elements may be most decidedly mixed ; and here is where much good faith is lost, when steam plants are to be laid and put in operation.

The man who buys and pays for a steam plant, whether stationary or marine, wants some definite statement ; he wants some pointed amount, not "as good as any of its class," "as well as such a ship" ; and the old unit of "so many" pounds of coal per horse power per hour, is as lacking in meaning as any sentence of so many words it is a possible thing to construct.

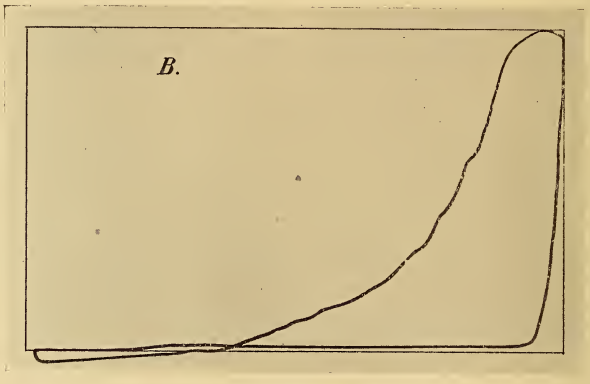
The proper use of the coal called for in the bill embodies a number of important elements, among which must be counted the use of experienced brains, in a way that must be disinterested in patents and commissions, but for the best results possible to obtain in that place and under that train of circumstances. The use and abuse of heat units have become a hackneyed subject, it has been worn threadbare, but we do know that with the most efficient use of coal and the heating surfaces exposed to its combustion we can approach closely the evaporation of twelve pounds of water into steam, and yet it is often quoted that that amount or more has been done ; but when more than twelve pounds per hour have been evaporated it is usually done "on paper," and for a purpose. As a well-known American engineer has said, and with truth on his side, "Such reports emanate only from a soda-water manufactory," and he might have added with perfect propriety, that the evaporation of a boiler could be reported at any figure within reason, if only the calorimetric value of the steam was not tested and reported, or if a certificate of the locking up of the "blow-off valve" was furnished, and this way of "testing" has taught the business man to beware of such operations.

On the other hand, reputable makers of all the paraphernalia of a steam plant spend money and time freely to establish the facts that they can accomplish a close approximation to the limit of possibility, and if steam users were to consider one simple point in this line they would save frequent and bitter disappointment. That point which is frequently overlooked is the measure of success of any firm or persons. Success is shown by the amount of business done through a period of years and by the repetition of orders from the same locality or firms, for men are not so constituted as to be easy victims to the same imposition the second and third times, and this point is frequently over-

looked. The amount of coal used is dependent on many and varying conditions, and from these we can take up only, as from experience we gather, that no man wastes coal from intention. How to burn it closely and clearly is to a great extent governed by the apparatus furnished, and when the plant is once in place and in operation, then there is little to be said or done except to make the most of the apparent conditions. That accurate methods of measuring the cost of the steam power exist in capable and experienced hands, and in intelligent units, to the satisfaction of the business man, cannot be denied, and there is not the least mystification nor

putations are made upon the diagrams from the accompanying data, it is found that A requires only 40.2 pounds of steam per horse power per hour, and B the amount of 39.2 pounds, or a difference of only 2½ per cent. as between the efficiency in commercial use of the extremes of good and bad practice as generally allowed.

For this there are good reasons, and when the cost of the power comes to be computed from the diagrams (not demonstrated in the figures) we find the engine from which A was taken was in perfect order, while B was leaking badly after the valve is apparently closed, so that a large amount of steam entered the



TAKEN FROM A CORLISS ENGINE.

need of long and abstruse formulæ; all these matters can be and are reduced to the least possible number of terms after careful examination in a straightforward way, and so that dollars and cents are the result.

Without going into details, two figures are shown with this article that are reproductions from the every-day work of engines in commercial use. A is taken from an ordinary link motion, carrying steam nearly full stroke, or one of the most uneconomical ways of working steam now known. B is from a modern Corliss engine, as well known to be one of the most economical engines in general use. When the com-

cylinder which did not do the work with any economy, or after the valve had made the motion of closing and had commenced the expansion that a very large amount of steam entered the cylinder, thus practically converting the supposed cut-off engine into an approximate use of non-expansive action during the latter part of the stroke, or losing in the last half of the stroke more than the gain apparently made and to be made in the first half.

The apparent diagram B is good looking, but upon the demonstration being made it is found to be most unsatisfactory and expensive, not in any manner of theory or opinion, but from the business

man's standpoint of dollars per day. This is a matter that few engineers can determine without pulling off the cylinder-head, and many of the novices who carry around an indicator would be equally helpless; yet the fact remains, A is doing as well as possible under its circumstances. B should do from 35 to 40 per cent. more work with the same steam that is actually used. The difference in the bill is footed by the owner or operator of the power, and makes it cost more or less as the conditions vary.

How much these conditional results vary can only be known by carefully looking up a number of cases and stating the conditions, which cannot be included in the present article, but may follow with illustrations, and the facts tersely given with such general deductions as may interest those who are interested in the commercial use of steam power and who wish to get the greatest amount of power out of a dollar's worth of coal, the usual adaptability used in the purchase of the fuel, and the best brains to mix with the shovel or "mechanical stoker."

SUBDIVIDED POWER.

WITH the improvement in machinery has arisen the question of the most economical application and use of power, and to the mechanical engineer no field offers greater scope and inducement than the solution of the problem of a diminished cost and saving of steam to the manufacturer.

The moderate subdivision of power is one of the practical results of modern engineering in this direction, and that it has taken a permanent and an increasing hold upon the larger steam users is evidenced by the favor with which it has been received by them.

All cases do not admit of the application of subdivided power, but when applied with sound judgment to conditions within reasonable bounds of adaptability the results obtained are thoroughly and uniformly satisfactory. To the mechanical engineer the question of transforming a plant from a single large engine equipment to one of several small engines (or subdivision of power) is one involving many issues. A plant covering a small and confined area, carrying an average constant load, and having no intricate and extensive system of shafting and belting, is operated far more economically than one carrying a variable load and covering several acres of land, or embracing separate buildings or many floors fitted with complicated shafting, belting, and pulleys.

This latter condition is an example where subdivided power could be properly introduced with advantage. Having a variable load, a number of small, independent engines located at the different points of industry will economically displace the long and useful reaches of shafting operated from a single engine. Shafting, belts, pulleys, etc., are required merely for the transmission of the power from the engine to the work. The consequent loss by friction, the constant use of oil, with its accompanying uncleanliness, and all the general repairs incident to wear and tear, and the settling of buildings, are factors which strongly urge the discontinuance of complex shaft and belt distribution. At first sight it would seem that the use of so many small engines would necessarily indicate the employment of several engineers to operate and maintain them; but so much has been done to simplify and perfect modern machinery, that only slight attention to the needs of these small engines is required by any local workman, who can, with but little loss of time, operate the nearest engine as the demands of power require. It is undoubtedly true in some degree where subdivision is carried to an extreme that a number of small engines of aggregate horse power is less saving in the use of steam and fuel than a single large engine of equivalent horse power; also, where the long reaches of steam pipe for subdivided power are carried over great areas, a

resulting possibility is condensed steam. But steam jackets and new devices for preventing condensation will ultimately overcome the latter objection ; and since the introduction of the compound engine in small sizes, the specific economy of which is equal to the best heretofore obtainable in the large engine, the former objection largely disappears. Again, the saving gained by increased horse power, where an intricate and extensive shaft and belt distribution is avoided, will commend itself as another quality.

In this connection it is known that an extreme of 35 per cent. dead load or loss in horse power has been known to exist in some large plants and mills resulting from an extensive development of shafting and belting. In a general case the loss will amount to 15 per cent., the variation depending upon the amount of work done and upon the size of plant.*

To successfully subdivide power the engine used must possess the essentials to survive a minimum of attention ; it must be indifferent as to location, as well as ready to start at a moment's notice, even after long idleness, and must be an engine that can be depended upon to run continuously without any particular limit as to time ; and while retaining in full simplicity compactness, economy of maintenance, and running quality, it must not be high-priced and render a small coal account. There are a score or more different engines built to meet such demands, and hundreds of large plants are daily operated by them in a successful and economical manner.

As regards cost of the two systems, for mills that will admit of subdivided power, the first outlay for independent engines, with their attachments, may possibly exceed that for the single large engine with its shafting, belts, etc.; but in many mills a single large engine implies a detached engine-room, while independent engines are necessarily within the body of the mill itself, sometimes below the main floor. The cost of foundations is, if anything, in favor of independent engines.

The whole subject of subdivided power, as well as its application to special cases in the form of direct connection, is one of large practical interest. While by no means to be universally recommended, it should be generally understood and considered as a factor in planning new mills or rearranging old ones. Good judgment will dictate in each case, but the advantages, when applicable, are manifestly on a sound engineering basis, and as such should command the thoughtful consideration of every manufacturer.

C. H. S.

* "On the Power Required to Overcome the Frictional Resistances of Engine and Shafting in Mills, and its Cost," by John T. Henthorne, Vol. VI, page 461, Transactions of the American Society of Mechanical Engineers.

WELDING AND FLANGING BOILER PLATES.

THE peculiar and at times apparently uncertain action of heat upon boiler steel is well known to manufacturers of boilers. In foreign practice boiler steel is welded much more than in America, and it is possible that boiler-makers who have not had good results when welding was attempted may obtain some information from the following letters, which were received in reply to our inquiry regarding welding and flanging heavy boiler steel. It would seem at first sight that a steel suitable for boilers would not be adapted for welding. We know of an instance of an experiment made under the direct supervision of a firm who have successfully welded light plate, but who utterly failed to get satisfactory results when it was attempted with heavy, hard steel of the best quality. Perhaps it would be more accurate to state that the plate was welded, but as the steel was put into such a condition that it cracked on each side of the weld (the weld itself seemed all right) it could hardly be called a successful piece of work. Yet there is no doubt that steel can be satisfactorily

welded, as is attested by several of the letters from firms who have done so. What the conditions should actually be, whether all boiler steel of low carbon, sulphur, and phosphorus, or high in these ingredients, can be welded if we "know just how," or if the conditions of good boiler steel are such as will make a good welding possible, would seem to be a good subject for investigation, and in some subsequent issue we hope to present some accurate data.

Now, regarding the local heating necessary for flanging. There seem to be little doubt that a piece of steel that has been partially heated or wholly overheated has been dangerously injured. In small shops, in making a boiler-head, the plate is heated many times before the flanging is completed, which necessary local heating and cooling, expansion and contraction, must have a bad effect upon the plate. When boilers are made of iron, this method may be adopted without danger, but we cannot believe that when hard steel is treated in that way the effect can be anything but disastrous. Then, again, if flanged to a very sharp corner, there is little doubt, even if the plate is wholly heated, the elongation or stretching on the outside and bunching on the inside can do the plate much harm. In flanging heavy plate for boiler heads it would seem that the best practice would be to wholly heat it to a low, red heat and then die-flange it at one operation, which of course necessitates only one heating.

EDITOR CASSIER'S MAGAZINE:

Referring to the injury done by locally heating and flanging thick boiler steel, we would say that the work on our Galloway boilers requires flanging and welding on plates ranging from $\frac{3}{8}$ to $\frac{9}{16}$ of an inch in thickness.

We avoid wherever possible local heating for the purpose of flanging, as it is difficult to so regulate this heat as to avoid burning the steel; and to so heat you must depend on the skill of the workman. All our boiler-head flanging is done by heating the entire plate in a furnace to a low red heat, and die-flanging the same at one heat and operation, thus avoiding the danger of many heats on one plate.

With our conical tube plates we are obliged to heat locally for both welding and flanging. To do this successfully requires the best soft steel, and the parties from whom we can buy such steel are limited. These welds have to stand tension when in service, but we test these so thoroughly before leaving the shop that we never have had difficulty from them, showing that the best soft boiler steel can be welded and then stand tension.

It is our invariable practice to anneal all steel that has been partially heated, as also all steel plates that have been sheared or punched.

We regret that we cannot cite from our construction of boilers instances of heavy boiler steel being locally heated and welded.

In our conical tube work we weld the tube and then flange the end to a right angle, which, of course, includes the flanging of the welded plate. This is a severe test of welded steel, but with good material it can be done successfully.

Yours truly,

WM. F. SELLERS,
Secretary Edge Moor Iron Company.
EDGE MOOR, September 28, 1891.

EDITOR CASSIER'S MAGAZINE:

My experience and judgment in the handling and working of boiler steel has been that the proper heating for flanging purposes does no injury to the steel, unless overheated, in which case it would certainly injure it. If flanged at right angles to a sharp corner, there would be danger the plate would probably be injured, and necessarily weakened at that point. But if flanged to a round corner, say on inside radius equal to twice the thickness of the material, it would not be injured. Boiler steel of low carbon, sulphur, and phosphorus can be successfully welded. Corrugated boiler flues and fire-boxes are largely used made of steel with welded seam. You ask if the weld has to bear a tension when the boiler is at work. It depends on what part of the boiler the weld is placed. In the case of being in a flue or fire-box there is no tension, only outside or collapsing pressure, but

for internal or bursting pressure there would be less certainty, because welded plates are never uniform and perfect, for which reason there are very few welded boilers in use in this country, but I have heard of some in Europe.

JAMES LAPPAN.

PITTSBURGH, PA., September 28, 1891.

EDITOR CASSIER'S MAGAZINE:

We believe heavy boiler steel would not be seriously injured by the necessary heating for flanging to a right angle of, say, 2° or 3° radius if properly heated and cooled.

We have never heard of boiler steel being welded for practical use, and do not think that there ever has been a boiler constructed with welded seams.

Yours truly,

PORTER MFG. CO., LIMITED.

S. WORDEN, *Sec'y.*

SYRACUSE, N. Y., October 12, 1891.

EDITOR CASSIER'S MAGAZINE:

In reply to your inquiry of the 26th, would say that in our experience the flanging of a heavy flat plate to a right angle is the most severe test that can be made on a boiler plate, especially where it is locally heated, owing to expansion and contraction being unequal on the plate, affecting the material to a greater or less extent, according to the quality and make of plate.

All boiler steel should be of such quality that will weld readily, and to stand the strain that may be required in the working of the boiler or flanging of the plate.

Yours truly,

R. MUNROE & SON.

PITTSBURGH, PA. September, 29, 1891.

EDITOR CASSIER'S MAGAZINE:

In reply to your inquiry of the 26th, will say good boiler steel is not injured by heating and flanging to right angle, —that is, with *proper* heating.

We weld boiler steel very satisfactorily; in fact, we weld our boiler punchings and cuttings into bars and use it for making screw-punches and other work where the greatest strength is required, and only have to make them a little over half as heavy as iron to stand the work.

We weld boiler steel for door-rings in oil-well boilers and portable boilers, and of course it bears the same tension as other parts of the ring while the boiler is at work.

Yours truly,

THE BROWNELL & CO.

DAYTON, O., September 28, 1891.

A manufacturer who does not wish his name printed writes as follows:

EDITOR CASSIER'S MAGAZINE:

Replying to your inquiry, I believe that boiler steel is not injured in flanging provided it is properly done. The method approved by the American Boiler Manufacturers' Association is as follows:

"The flanging of steel should be done at not less than a good red heat, and not a single blow should be given after the plate is cooled down to less than cherry red by daylight. After flanging, all plates should be annealed simply by uniform cooling from an even dull red heat for the whole sheet in the open air."

I think if this plan is adhered to the plate is not injured, but I certainly discountenance flanging to a perfect right angle. It should have a radius of at least the thickness of the steel.

A MEMBER OF THE AMERICAN BOILER MANUFACTURERS' ASS'N.

EQUATION OF PIPES.

IT is frequently desirable to know what number of one-sized pipes will be equal in capacity to another given pipe for delivery of steam, air, or water. This has been carefully computed by a well-known engineer and has been published in the book "Steam," issued by the Babcock & Wilcox Company, by whose permission we print the table below. At the same velocity of flow two pipes deliver as the squares of their internal diameters, but the same head will not produce the same velocity in pipes of different sizes or lengths, the difference being usually stated to vary as the square root of the fifth power of the diameter.

The friction of a fluid within itself is very slight, and therefore the main resistance to flow is the friction upon the sides of the conduit. This extends to a limited distance, and is, of course, greater in proportion to the contents of a small pipe than of a large. It may be approximated in a given pipe by a constant multiplied by the diameter, or the ratio of flow found by dividing some power of the diameter by the diameter increased by a constant. Careful comparison of a large number of experiments, by different investigators, has developed the following as a close approximation to the relative flow in pipes of different sizes under similar conditions :

$$W \propto \sqrt{\frac{d^6}{d+3.6}} \quad \text{or,} \quad \frac{d^3}{\sqrt{d+3.6}}$$

W being the weight of fluid delivered in a given time, and d being the internal diameter in inches.

The diameters of "standard" steam and gas pipe, however, vary from the nominal diameters, and in applying this rule it is necessary to take the true measurements, which are given in the following table :

TABLE OF STANDARD SIZES, STEAM AND GAS PIPES.

Size, in.	Diameter.		Size, in.	Diameter.		Size, in.	Diameter.	
	Internal.	External.		Internal.	External.		Internal.	External.
⅛	.27	.40	2½	2.47	2.87	9	8.94	9.62
¼	.36	.54	3	3.07	3.5	10	10.02	10.75
⅜	.49	.67	3½	3.55	4	11	11	11.75
½	.62	.84	4	4.03	4.5	12	12	12.75
¾	.82	1.05	4½	4.51	5	13	13.25	14
1	1.05	1.31	5	5.04	5.56	14	14.25	15
1¼	1.38	1.66	6	6.06	6.62	15	15.43	16
1½	1.61	1.90	7	7.02	7.62	16	16.4	17
2	2.07	2.37	8	7.98	8.62	17	17.32	18

The table below gives the number of pipes of one size required to equal in delivery other larger pipes of same length and under same conditions. The upper portion above the diagonal line of blanks pertains to "standard" steam and gas pipes, while the lower portion is for pipes of the *actual* internal diameters given. The figures given in the table opposite the intersection of any two sizes is the number of the smaller-sized pipes required to equal one of the larger. Thus, it requires 29 standard 2-inch pipes to equal one standard 7-inch pipe, or 9717 standard ½-inch pipe to equal one 17-inch pipe.

TABLE OF EQUATION OF PIPES.

STANDARD STEAM AND GAS PIPES.

Dia.	½	¾	1	1½	2	2½	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Dia.
½		2.27	4.88	15.8	31.7	52.9	96.9	205	377	620	918	1,292	1,767	2,488	3,014	3,786	4,904	5,927	7,321	8,535	9,717	½
¾	2.60		2.05	6.97	14.0	23.3	42.5	90.4	166	273	405	569	779	1,096	1,328	1,668	2,161	2,615	3,226	3,761	4,282	¾
1	7.55	2.90		3.45	6.82	11.4	20.9	44.1	81.1	133	198	278	380	536	649	815	1,070	1,263	1,576	1,837	2,092	1
1¼	24.2	9.30	3.20		1.26	3.34	6.13	13.0	23.8	39.2	58.1	81.7	112	157	190	239	310	375	463	539	614	1¼
1½	54.8	21.0	7.25	2.26		1.67	3.06	6.47	11.9	19.6	29.0	40.8	55.8	78.5	95.1	119	155	187	231	269	307	1½
2	102	39.4	13.6	4.23	1.87		1.83	3.87	7.12	11.7	17.4	24.4	33.4	47.0	56.9	71.5	92.6	112	138	161	184	2
2½	170	65.4	22.6	7.03	3.11	1.66		2.12	3.89	6.30	9.48	13.3	20.9	23.7	31.2	39.1	50.6	61.1	75.5	88.0	100	2½
3	376	144	49.8	15.5	6.87	3.67	2.21		1.84	3.02	4.48	6.30	8.61	12.1	14.7	18.5	23.9	28.9	35.7	41.6	47.4	3
4	686	263	90.9	28.3	12.5	6.70	4.03	1.83		1.65	2.44	3.43	4.69	6.60	8.00	10.0	13.0	15.7	19 4	22.6	25.8	4
5	1,116	429	148	46.0	20.4	10.9	6.56	2.97	1.63		1.48	2.09	2.85	4.02	4.86	6.11	7.91	9.56	11.8	13.8	15.6	5
6	1,707	656	226	70.5	31.2	16.6	10.0	4.54	2.49	1.51		1.41	1.93	2.71	3.28	4.12	5.34	6.45	7.97	9.31	10.6	6
7	2,435	936	322	101	44.5	23.8	14.3	6.48	3.54	2.18	1.43		1.35	1.93	2.33	2.92	3.79	4.57	5.67	6.60	7.52	7
8	3,335	1,281	440	137	60.8	32.5	19.5	8.85	4.85	2.98	1.95	1.37		1.41	1.71	2.14	2.77	3.35	4.14	4.83	5.50	8
9	4,393	1,688	582	181	80.4	42.9	25.8	11.7	6.40	3.93	2.57	1.80	1.32		1.21	1.52	1.97	2.38	2.94	3.43	3.91	9
10	5,642	2,168	747	233	103	55.1	33.1	15.0	8.22	5.05	3.31	2.32	1.70	1.28		1.26	1.63	1 88	2.43	2.83	3.22	10
11	7,087	2,723	938	293	129	69.2	41.6	18.8	10.3	6.34	4.15	2.91	2.13	1.61	1.26		1.30	1.57	1.03	2.26	2.58	11
12	8,657	3,326	1.146	358	158	84.5	50.7	23.0	12.6	7.75	5.07	3.56	2.60	1.98	1.53	1.22		1.21	1.49	1.74	1.98	12
13	10,600	4,070	1.403	438	193	103	62.2	28.2	15.4	9.48	6.21	4.35	3.18	2.41	1.88	1.50	1.22		1.24	1.44	1.64	13
14	12,824	4,927	1,698	530	234	125	75.3	34.1	18.7	11.5	7.52	5.27	3.85	2.92	2.27	1.81	1.48	1.21		1.17	1.35	14
15	14,978	5,758	1,984	619	274	146	88.0	39.9	21.8	13 4	8.78	6.15	4.51	3.41	2.66	2.12	1.73	1 42	1.18		1.14	15
16	17,537	6,738	2,322	724	320	171	103	46.6	25.6	15.7	10.3	7.20	5.27	3.99	3.11	2.47	2.03	1.66	1.37	1 17		16
17	20,327	7,810	2,691	840	371	198	119	54.1	29.6	18.2	11.9	8.35	6.11	4.63	3.60	2.87	2.35	1.92	1.59	1.36	1.16	
18	23,670	9,096	3,132	978	432	231	138	63.0	34.5	21.2	13.9	9.72	7.11	5.39	4.19	3.34	2.73	2.24	1.85	1.58	1.35	
19	27,350	10,510	3,619	1,130	499	267	160	72.8	39.9	24.5	16.0	11.2	8.22	6.23	4.84	3.86	3.16	2.59	2.14	1.82	1.56	
20	31,300	12,030	4,142	1,293	571	305	183	83.3	45.7	28.0	18.3	12.8	9.41	7.13	5.54	4.42	3.62	2.96	2.45	2.08	1.78	
21	35,520	13,650	4,700	1,468	648	346	208	94.5	51.9	31.8	20.8	14.5	10.7	8.09	6.29	5.02	4.11	3.36	2.78	2.36	2.02	
22	40,000	15,380	5,295	1,653	730	390	234	106	58.4	35.8	23.4	16.3	12.0	9.11	7.08	5.65	4.63	3.78	3.13	2.66	2.28	
23	44,800	17,220	5,928	1,851	817	436	262	119	65.4	40.1	26.2	18.3	13.4	10.2	7.93	6.33	5.18	4.23	3.50	2.98	2.55	
24	42,624	16,376	5,644	1,761	778	416	250	113	62.1	38.2	25.0	17.5	12.8	9.70	7.55	6.01	4.92	4.02	3.32	2.84	2.43	
30	75,453	28,990	9,990	3,117	1,378	736	443	201	110	67.6	44.2	31.0	22.7	17.2	13.4	10.7	8.72	7.14	5.88	5.03	4.30	
36	120,100	46,143	15,902	4,961	2,193	1.172	705	319	175	108	70.4	49.3	36.1	27.3	21.3	16.9	13.9	11.3	9.37	8.01	6.84	
42	177,724	68,282	23,531	7,341	3,245	1,734	1,044	473	259	159	104	73.0	53.4	40.5	31.5	25.1	20.5	16.8	13.9	11.9	10.1	
48	249,351	95,818	33,020	10,301	4,554	2,434	1,465	663	363	223	146	102	75.0	56.8	44.2	35.2	28.3	23.5	19.4	16.6	14.2	

Dia.	½	¾	1	1½	2	2½	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Dia.

ACTUAL INTERNAL DIAMETERS.

PROFIT-SHARING ENTERPRISES.

AT the June meeting of the American Association of Mechanical Engineers, Mr. F. A. Halsey read a paper in which he set forth a method of paying for labor which was designated as a "premium plan." Mr. Halsey's idea was to determine how long it should take, say, to bore a cylinder of a certain size and form. This would be calculated on what the average time had been for a number done by day's work. Then if the workman could by ingenuity, or hard work, or in any way cut down the time necessary for making a similar cylinder, he was to be credited with part of the difference between the time saved over the day's work schedule. If, for instance, it had previously taken a man two days at, say, $3 per day, and he cut the time to one day, he should get part of the time he had saved his employer, which would serve as a stimulus for him to effect methods of reducing the time on other work. It would seem that such a plan, while having failings, as all plans do, would be superior to any of those advanced by the "Board of Trade" in England. That ably-edited journal, *Engineering*, speaking of the report, in the issue of February 13, said it was a very disappointing document in many respects. To quote them exactly: "It has, however, this advantage, that it is 'official,' and it brings within the reach of the public some authentic information on a subject which has been much talked about for over twenty years. It has long been a matter of regret and of astonishment that the reports of the Labor Correspondent to the Board of Trade during the last five years have contained no reference to the profit-sharing schemes in existence, one of which dates back to 1869, a period of twenty-one years. A labor bureau, which is officially unconscious of such a method of dealing with labor difficulties, seems scarcely to fulfill its functions; it certainly does not realize the reasonable expectations of those who welcomed its establishment. The report defines the term profit-sharing as 'having this principle in common, that the people engaged in the concern, or an appreciable portion of these workers, shall receive in addition to their salary or wages some pecuniary advantage, prospective or immediate, to be paid out of the net profits in any year in which net profits are made.' It then proceeds to describe the chief forms of profit-sharing, by which this advantage is secured. Thus: (*a*) The bonus system, by which a cash payment, in the shape of a gift or thank-offering to the workers, or a portion of them, is distributed in recognition of the success achieved in the year. (*b*) The institution of a provident fund, to which is paid over a definite portion of the profits in each year, for the benefit of the participating workmen in cases of sickness or old age. (*c*) The setting aside of a share of the profits and allotting it to labor as extra wage, to enable the workmen to become joint owners in the concern, in recognition of the prosperity which their labor has helped to create, or increase in amount. (*d*) The distribution of a definite share of the net profits to the workmen in proportion to their wages, or to each man's contribution in labor to the total labor performed. Practically the first-named method and the last are in most respects identically the same. The mode of distribution being settled and agreed upon, 'each workman is invited to consider his own labor as an improvable quantity, an item in the business enterprise which his own will may render more useful to the general result, and to look forward to a reward for his extra contribution, beyond the wages paid for labor, to a share of the profits at the end of the year.' The divisible profits are regarded as an extra amount paid out of a fund which owes its existence to the profit-sharing system, above and beyond what would otherwise be ordinarily earned in the undertaking. The supposed sources of increased profit are said to be: (1) Reduced waste of material; (2) superior excellence of the work; (3) diminished cost of superintendence; (4) greater stability in the staff, and less risk in the enterprise; (5) improvements in manufacture and processes, by stimulating the workers to

bring practical information to bear upon their work, and by aiding the staff with suggestions as occasion may arise. The advantages thus accruing would, it is contended, increase the output, reduce the cost of production, and promote the progress and advancement of the firm or concern. It is stated that a considerable increase in the profits has resulted where the system has been tried, and that therefore the distribution to the workpeople is not a transfer of any portion of ordinary profits from the employers to the employed, but a distribution of the extra amount created by the employés in consequence of the arrangement entered into.

"There is little doubt that economy in production depends in many cases upon the workers. These may either increase or diminish the cost very materially; not merely by avoiding actual waste, but by utilizing to the best advantage the whole of the materials committed to their care. Willful waste on the part of employés might be altogether exceptional, may be even regarded as a gratuitous insult to the integrity of the workers; but without even insinuating that there is willful waste in any case, there is all the difference in the world between a careless use of materials and that economical use which naturally arises if the user has a direct personal pecuniary interest in making the most of every bit of material with which he has to deal. Every fraction of waste reduces the profit, by increasing the cost of production; if, therefore, this waste can be avoided, or even minimized, profits will be proportionately increased. But it is not only in material that a great saving can be effected. In all trades where the work is performed by time-workers the cost of superintendence is large, and necessarily so. The interest of the workers is limited to the wage per hour, day, or week, as the case may be. Payment for assiduity is scarcely thought of. In large firms a kind of rough average is struck of the actual work performed by ten or twenty men, quick and slow together, and by this gage the actual cost of production is measured. The foreman or overlooker has all his work to do to so apportion the labor that the final result shall be within the estimate cost; and the superintendence has to be increased in proportion to the number employed, and to the diversified nature of the work. Where the workers have a direct interest in the progress and prosperity of the firm, they need little, certainly less, superintendence than is required where no direct personal interest is present as a stimulus to exertion and output.

"The excellence of the work does not depend so much upon the system adopted as the writer of the report appears to imagine. The firm, or the employer, has a standard of excellence which it is sought to attain, and for which end the workers are selected. If, however, both the employer and employed were actuated by the same desire, each having a personal interest in attaining it, then the firm or concern would speedily acquire a reputation for its work, and would prosper accordingly. It is not only possible, but probable, that many firms have lost enormously by the passing out of their hands of improvements in manufacture, and the application of new processes, which their own workmen have perfected, but which have gone to other firms because the inventor or discoverer had no direct pecuniary interest in the concern, and possibly no encouragement to make known his improvements or inventions. There is, in fact, no real mutuality in our ordinary methods of industrial enterprise, certainly there is little or no permanent mutuality in it. The exchange is, wages for labor, and *vice versa*; but where the profit-sharing principle is in operation there is the higher or more lasting bond of mutual interest. We often hear the expression that the interests of capital and labor are identical. They should be, but they are not, under existing conditions. There is some approach to an identity of interests under a system of profit-sharing, where all have a proportionate share in the progress and prosperity of the concern; but there is not much in the nature of identity where the man is hired by the day, gets his wages for his work, and is dismissed. What bond of union is there, or can be in such a case, between the employer on the one hand, and the workman on the other?

"There is none, and of course there

can be none under such circumstances. The difficulty in all cases between labor and capital is in the adjustment of the means. There is, perhaps, less difference as to abstract principles than many suppose. The question is how to bridge over the gulf. In other words, is it possible to institute a system which will insure to capital its rightful dues, and to labor its due reward? Many think that the profit-sharing principle can and will achieve this end. It has been tried, it has succeeded; it has passed the experimental stage, and is now in operation; in one of the firms enumerated it has been tried for twenty-one years, ever since 1869. About fifty firms are enumerated in the report as having adopted the system, employing over 11,000 persons. The number is small, and the principle has not extended so rapidly as the co-operative system, but sufficient progress has been made to test its operation and its results. Out of the fifty firms mentioned, seven are connected with the engineering branches of trade, and one other, Messrs. Tangyes, at Birmingham, adopt it partially. Unfortunately, only one of the firms seems to have had any lengthened experience of the system, that of Messrs. Bailey, Nokes, & Co., of the Rolling Mills, Birmingham. The others have been established more recently. In five cases the profits are shared on the bonus system by a cash payment, in one instance by a cash payment and by a donation to the provident fund, and in one instance by the provident fund only. In the printing and paper trades about a dozen firms adopt it, some paying a cash bonus, others to a provident fund, and others by both methods. In France about eighty firms are conducted on this principle; in the United States twenty-three firms are enumerated as having adopted it; there are also several in Germany, Switzerland, Belgium, and elsewhere. The information as to the financial operation and results of the system is somewhat meager. The success of the Maison Leclair is beyond all question; it has stood the test for forty years. The firm of Laroche-Joubert et Cie. has also scored a great success, the dividends in the latter being about a million and a half of francs. In this case dividend is divided among employés, on salaries and wages, on capital above 5 per cent., and customers. The South Metropolitan Gas Company distributed a bonus of over £5377 to June 30, 1890, the withdrawals to December 31, 1890, being over £3628, the savings nearly £2967, and the stock bought by the men £1657 14s. In this company the bonus is based on a sliding-scale, beginning at 1 per cent. and going up to and over 8 per cent., the ratio being 1 per cent. per penny on the price of gas. Only those under written agreements are entitled to the bonus. Some details are given of several firms where the system has been adopted, and the views of the heads of the firm are set forth. On one point the evidence seems to be satisfactory,—there is no difficulty in the management. The men do not interfere, they have no authority to interfere, and they show no disposition to interfere. The firms testify that the employer's authority is not crippled; that there is now peace, where formerly there were disputes and disagreements; that the concerns have prospered by the methods adopted; and that the profits realized have amply compensated them for the share divided. As a first contribution to the literature of the question, the report is useful, but it is to be hoped that further information will be given showing the financial results in all cases where adopted, in so far as the firms are willing to make known those results."

GAS AS A REFRIGERANT.

A DISPATCH in the daily papers informs us that Mr. S. P. Sticker, of Buffalo, N. Y., claims to have discovered a method of making ice by means of illuminating gas, which may be returned without deterioration to the mains after use, according to London *Iron*. In the course of experiments in the works of the Provincial Gas Company at International Bridge, Ont., he produced a temperature of 80° below zero by the use of water and gas only, without chemicals.

ASSOCIATIONS OF STATIONARY ENGINEERS.

THE high pressure of steam now being employed in connection with the multiple-expansion engines is bringing to the front more than any other argument the need of engineers of higher order of intelligence and experience. The "steam users," the men who pay the coal bill, in the race for wealth through competition find themselves compelled to economize in every direction. All possible items of expense must be cut down and at the same time every improvement that can be utilized for economy is purchased. In this "squeezing" but at the same time improving process, many firms whose coal bill is very large do not recognize the engineer as a factor of possible economy, but select anyone whom they think can open a valve or squeeze an oil can. It has remained for the engineer himself to convince them this is a mistake, not by resort to heated controversy or by strikes, but by perfecting himself in the knowledge of his profession—for a profession it surely is—and proving to the manufacturer that there is no more economy in employing an engineer because he will work for almost nothing than there would be in placing important work in the hands of ignorant draughtsmen, superintendents, or bookkeepers. On another page in this magazine in an article written by Thomas Pray, Jr., two diagrams are shown taken from two styles of engines. One of them from a Corliss engine shows that it cost 35 per cent. more in coal to produce the power that was used than would have been necessary had the engine been in the condition which a competent engineer should have been able to place it. Suppose 15 tons of coal a week were being used where 10 tons would have been sufficient. Five tons of coal a week at, say, $4 per ton would amount in a year to the snug little sum of $1000. That amount represents the cost to the manufacturer of the difference between competency and incompetency. But a waste of 5 tons a week is very small compared to some plants which the writer has had opportunity to learn about, and there is no doubt that there are thousands of engines running to-day from steam produced in a fairly satisfactory manner, but wasted as soon as it reaches the engine. The engineer in charge does not know it; the manufacturer does not know it. He has been used to paying large coal bills, and if by some chance a smaller amount would be required he would be very much surprised.

The great factor in the education of engineers has been the formation of associations with their regular meetings where experiences are talked over and ideas discussed. Up to nine or ten years ago there was no general society of working engineers; here and there a few men had formed local organizations, but aside from the social intercourse which resulted very little good was accomplished. It remained for Mr. H. D. Cozens, at the time an engineer in Providence, R. I., to arrange for the formation of a national order. Out of the idea he suggested and the small beginning at a meeting in New York in 1882, where but eleven delegates were present, has grown the National Association of Stationary Engineers. From an initial membership of six or seven hundred, and eleven local associations, there has grown a grand society of about seven thousand members and some two hundred separate branches.

In addition to this association are a dozen or more distinct organizations, the most prominent among which are the American Order of Stationary Engineers and the Eccentric Association, whose combined membership is many thousand more.

The distinct aim of nearly all these associations, as well as the National, is improvement, and they all appear to fully believe in the "survival of the fittest." The by-laws of the National Association contain a section which prohibits any local order from participating in strikes, and among its members are men who are receiving high salaries and who occupy important positions which they retain solely because they are com-



WILLIAM POWELL,

President National Association of Stationary Engineers.

petent. While a membership in an engineers' association does not necessarily imply that the engineer is competent, there is no doubt that the influence exerted and the opportunity for education furnished are very great in such organizations and must of necessity be of much value to the engineer.

There is a suggestion which the writer wishes to make to the National Association.

At each meeting of the American Association of Mechanical Engineers and various other associations such as mining engineers and naval engineers there are read papers which have been prepared, printed in advance, and circulated among the members, who are allowed to write a "discussion" or opinion of the same several weeks in advance of the meeting. If this was done, many new facts and ideas which the working engineer obtains from time to time might in this way be carefully considered which if left to the time of the meeting would probably be forgotten. The printing of these papers would of course involve expense, but divided among a large membership it would be inconsiderable, while the possible benefit would be incalculable.

In the choice of presidents the National Association seems to have been very fortunate. Mr. Farenbach, Mr. Illingsworth, and now Mr. Powell are all experienced engineers in direct charge of large steam plants. Wm. Powell, the newly-elected president, whose portrait is printed on the preceding page, is the chief engineer of the pumping station of the Standard Oil Company in Cleveland. He was born in Monmouthshire, England, about forty-five years ago, and after an an apprenticeship in South Wales as a mechanical engineer came to America. He has had a practical experience in marine as well as stationary engineering and is probably the most popular engineer in Cleveland. Last year he was elected the vice-president and at the annual meeting in Omaha in September was honored by being made the chief executive of the organization.

PIECEWORK OR DAYWORK*

IT is the avowed object of many trade unions to limit piecework, and eventually to abolish it altogether. The reason put forth is that a greater number of men are required to do a given amount of work when paid by the hour than when paid by the piece, and that consequently the reward is divided among a larger number. On the face of it this looks like a "self-denying ordinance." The majority willingly give up the enhanced wages that follow increased exertion in order that employment may be found for an unemployed minority. Such an example of the solidarity of labor would not fail to arouse our respect and sympathy, if it could be shown that it was a genuine exhibition of brotherly kindness, and not merely a specious plea put forward to cover other springs of action. Such disinterested conduct is very rare in the world. We look in vain for it among "the classes" among whom competition is very keen. Even when they form themselves into close bodies—trade unions of another kind—they show no consideration for the weaker members. The practice of a barrister is hemmed in with rules and restrictions enforced by his inn or by the mess, yet there is nothing in them tending to divert fees from the more to the less successful. It is rather the other way; the junior is expected to "devil" for nothing, while the Q. C. pockets the fees; the leader enters the court absolutely ignorant of the case in hand, expecting to find that his companions in stuff have thoroughly mastered it; possibly he never comes at all, leaving them to do the work, and yet he takes the lion's share of the fees. In the medical profession etiquette prevents the young man from pushing himself forward, but it does not require the well-established practitioner to abate

* In *Engineering*, London, August 28.

one jot of his advantage. There is no rule in any of the regulated professions, as far as we have ever heard, that affords any advantage to the man who would naturally fall behind in the race, at the expense of those better fitted by nature or fortune to gain a front place. How comes it, then, that the working-classes organize their associations on such a more generous basis?

The secret of success of workpeople's organizations is written in their name; they are "unions," and as such must be founded on mutual forbearance and sacrifice—in the subordination of personal advantages to the general good. They only become powerful when they include a very considerable proportion of the class of workers that they represent, and to do this they must appeal strongly to the average man. This fact is forced home to them the first time they come into conflict with the capitalist. Unless they can lock the doors of the labor market against him he contrives to fill their places. The union is thus obliged to offer increased attractions to those outside it, and to pay the cost of them. Now the greatest benefit the workingman can have is regularity of employment, and to gain this he will forego his independence of action and the extra gains that come to him from spells of piecework and overtime. Hence early in the history of unionism it became an accepted doctrine that these practices should be put down as far as possible, in order that the laborers might be welded into a solid body able to hold its own in contests concerning wages.

If the working-classes believed that they received the same rate of pay per unit of work when working by the piece as when working by the hour, the abolition of piecework would be a genuine sacrifice on the part of the more skillful of them, who thus submit to a reduction of wages varying from 20 to 50 per cent. But there is a widespread belief that the capitalist gets his work done more cheaply when he adopts the system of payment by results. The man makes time and a third, but he believes that the master makes double time and even more. We believe that in the trades in which piecework is universal this view is quite correct, and that the cost of manufacture is much less than it would be if fixed wages were paid. For instance, in the cotton trade the great increase in the speed of machinery which has taken place in the last few years has only been rendered possible by the fact that the hands welcomed every improvement because it added to the weight that they could get off their spindles.

If they had been on daywork they would have been quite unable to respond to the demands made on them, and the old rate of speed must have been maintained. If it were attempted to run a mill now on regular wages, they would have to be arranged at such a low figure that the operatives could not live. Those who are now on piecework do not earn on the average much more money than dayworkers of equal skill in other industries. In all trades in which piecework is the universal rule, the tendency is to arrange prices so that the average earnings are very little above the general rate in the corresponding labor market. In cases, however, in which both kinds of work must prevail, as in engineers' shops, there is no chance of such a result occurring. There is a certain defined rate for daywork, and the piece-worker will insist on getting a fair advance upon it. Whether he or his employer gets the greater proportion of the advantage is a matter of bargaining. It is quite possible for either to appropriate it all. Cases occur in which the workman can make 25 or 33 per cent. additional to his wages without any additional exertion whatever, in which case his employer loses the additional wages. In the fair conditions, in which the extra pay is earned by a correspondingly increased effort, the master has the advantage of turning more work out without any increase of capital. He increases his business without adding to his rent, taxes, and depreciation, and thus gains an augmented profit.

As long as both daywork and piecework coexist in any trade, the latter is sure to be the better paid. The danger only arises for the workman when daywork is growing extinct. He may then justly dread that he is in danger of getting the worst of the bargain. There

are, however, many manufacturing businesses in which it is practically impossible that piecework should become universal, due to the great variety of the work turned out and the constant succession of novelties. But it is just in these cases that the unions offer the greatest opposition to it, and talk the loudest about letting every man have his share of what is to be done. As we have already said, this is done partly to gather recruits, but, beyond this, it has its spring of action in a keen knowledge of workshop practice. On piecework every fluctuation in the volume of trade is felt by the workpeople, and is reflected in the amount of wages earned. In a remote degree they share the master's fortune. Variations in prices do not affect them so long as the volume of trade is not reduced, but immediately things fall slack their wages are reduced. Now in a daywork shop this is not the case to the same extent. When new work ceases to be brought forward a whisper is sent around that jobs must not be hurried over, and without any actual idling the rate of progress is greatly curtailed. The output can be easily reduced by 30 per cent. without any decrease in the wages sheet. In individual cases a marvelous faculty is sometimes developed in keeping a job going for an extraordinary time. Every one knows the reply of the Lancashire millwright's son when asked when he and his father would finish certain repairs and go. He replied, "Father's gone to look for another job, and if he gets it we shall finish here to-morrow; but if he does not, Heaven only knows when we shall finish." If they had been on piecework such careful nursing of their job would have been impossible.

Another objection to piecework arises from the fact that it throws upon the workman all the losses that may arise from his being out of health or condition. If a dayworker finds himself on a Monday morning with relaxed muscles and an aching head, he may manage to make sufficient show of working to escape the foreman's censure. But if his pay depends on his exertions he had better stay at home and prepare himself for the next day, for his earnings will either be insignificant, or they will be gained at the expense of much pain and weariness. Many men, again, are quite unable to bear the strain of constant exertion; they can go on well enough at a jog-trot pace, but if they attempt to drive themselves at an increased rate their nature soon rebels, and insists on having a holiday, or a "spree," which more than consumes their extra pay. On the whole, the average mechanic finds himself happier, and very often richer, on good day wages than with the fluctuating gains of piecework.

The chief reason of the dislike to piecework is, however, as lately pointed out by Mr. David F. Schloss in the *Economic Review*, the incorrect ideas on the subjects of trade and finance held by many of the union leaders. They teach that when a man works hard he defrauds his fellow of his share of the possible earnings and is disloyal to his class. They represent wages as something wrung from the pockets of the capitalist, like territory taken from a defeated foe, and set forth that every effort should be made to swell their volume. Not only should the rate of pay per hour be increased, but the rate per unit of work done should be augmented. It would appear as if the union leaders often imagine that the amount to be done has no relation to the price, and that customers in want of goods must supply their needs without reference to what they cost. If this were the case, it would be reasonable for the working-classes to take advantage of every circumstance to swell their gains. Unfortunately such an idea is entirely fallacious, although there are times when it appears as if the demand increased as the prices went up. Such cases are merely accidental, and the sales made during periods of rapid inflation form only a very small proportion of the total trade. Buyers cannot purchase more than their resources permit, while those who are abroad will place their orders in the cheapest market. It is the long period of low prices that renders the rapid rush of good terms possible.

Economical methods of working may be fitly compared to improved tools. As Mr. Schloss points out, no rational person would dream of advocating a

return to the instruments of the savage with the idea of benefiting the workingman. And yet this is the logical corollary to a system which inculcates that a man should do less than a fair day's work in order that a second man may be employed to do the remainder. The workman's wages can never be more than the value of the work that he does, unless he appropriates each week a part of his employer's capital. Therefore the way to raise wages is to augment the efficiency of the laborer. A very great increase has taken place during the last half-century by the systems of "division of labor" and "interchangeability of parts," and by the use of better tools. Of the benefits resulting from improved machines and processes, the working-classes have received their full share, partly in increased wages, but more especially in the great reduction of prices. When they have found how great advantages come from the cheapening of processes, it is difficult to understand why they should offer such a strenuous opposition to piecework, except on the same ground that they combined to break machines and burn factories in days gone past. It is pardonable in the individual to resist change, for no alteration is made without some one suffering, but we expect a wider vision from men occupying the position of leaders, and who have the interests not only of the present, but also of the rising generation in their hands.

CORLISS CYLINDER-BORING MACHINE.

On another page is shown an illustration of a new special labor-saving machine recently brought out by the Niles Tool Works, of Hamilton, O. It was originally intended for work on Corliss engine cylinders, but, as can be seen, is also well adapted to other similar work. It is designed to bore Corliss cylinders of any size up to 42 inches in diameter and 10 feet long, and face the ends as well as bore the valve-ports all at one operation, the port-boring spindles having a traverse of five feet.

The driving cone has five steps for a 5-inch belt and operates through bevel and tangent gearing, which should insure smooth and steady action, while the driving-worm wheel is mounted upon a large sleeve-spindle running in the headstock, to which the boring-bar is clutched. This sleeve carries also a facing-head, which is clamped to the sleeve when in use and at other times swings down out of the way.

The boring-bar communicates motion to a second sleeve and facing-head mounted on the tailstock, which is adjustable along the bed to bring the facing-heads to any desired distance apart. Geared rack and pinion motion is also provided for fleeting the boring-bar through the tailstock to facilitate the admission of work.

The cutter-head is fed along the bar by means of a screw driven from a clutch in the head, which is operated from the tailstock end, and has also hand-adjustment by means of a hand-wheel placed at the end of the bar.

Two saddles for holding work are provided, which extend across the bed and are clamped to it.

Attached to the main bed on each side is an auxiliary bed upon which are mounted a pair of strong columns adjustable on the bed to any required position. One of these columns has either one or two saddles upon it, as may be desired, carrying spindles for boring valve-ports. These saddles are adjustable on the column and are counterbalanced. Power is communicated from an independent countershaft. The second column carries adjustable saddles for outboard bar-bearings. Each spindle is independent in its action and has independent power feed; and both saddles and spindles have quick hand-movements for rapid setting. Two boring-bars are used, one 7 inches diameter for cylinders up to 18 inches, the other 12 inches diameter for larger cylinders.

THE BOILER MANUFACTURERS' ASSOCIATION.

ABOUT two years ago, when the idea of forming an association of boiler manufacturers was first conceived by Mr. A. F. Douchett, he went to Mr. James Lappan, a well-known boiler manufacturer of Pittsburgh, who entered heartily into the plan, and together, after much labor, they succeeded in arranging for the first convention, which was held in Pittsburgh in April, 1889. The growth and influence of the American Boiler Manufacturers' Association has been very large already, for the time for organizing such a society was very opportune.

It is only during the last few years that high pressures have been demanded, and with the triple-expansion engine, which is already on the way to succeed the compound, still higher steam power must be furnished in order to obtain economic results.

To safely carry such pressure as even 150 pounds, which is as high as any horizontal tubular boiler carries, so far as we know, which is insured by the Hartford Steam Boiler Inspection and Insurance Company, only the very best material should be used, and it should be so constructed that it would be absolutely as safe as one carrying from 60 to 100 pounds. But 150 pounds is not where the demand will stop. Every indication now points to 200 pounds as the limit for the multiple-expansion engines which we are only commencing to build.

The need of some recognized standard of strength, quality of the material, and method of making the boiler is apparent to everyone.

It is a curious fact, that while the government recognizes the need of supervision and control of steam boilers as far as they are located in vessels, and of course exercises this control in order to protect the lives and property of people who might stand in danger therefrom, there has been no law or regulation enacted for similar protection for those on land.

With the exception of the influence exerted by the insurance company of Hartford, who compel the use of certain standards of construction in all boilers they insure, there is nothing to prevent any boiler-maker from using any kind of material or from constructing the boiler in any manner he sees fit, to suit the price offered by the intending purchaser.

In England the control lays with Lloyds or the Board of Trade, who make investigations regarding explosion or can compel the use of certain material, and whose decisions are enforced.

In many States the incompetent engineer, whose only qualification is his willingness to work for a dollar a day, is an added danger to the original faulty construction of the boiler.

Hardly a day passes which does not record one or more explosions with the usual accompaniment of lost lives.

It is a noticeable fact, however, that hardly any of the boilers which explode are insured by the company we have mentioned, which is sufficient proof that boilers can be made safe and kept so by the necessary examination from time to time.

Unfortunately this exemption from danger only exists in the insured boilers, while there are thousands in operation not alone faulty in first construction, but becoming more dangerous for lack of proper care and examination. Of course even the insured boiler cannot always be considered perfect, for the reason that the actual tests of the steel or iron cannot be made, and while the quality may be inferior,—made so that the price may meet the demands of competition, —the defect may not be discovered by the ordinary hydrostatic or steam tests.

Of course there are other abuses in the manufacture of boilers, as, for instance, omitting, say, one-third or more tubes or in some other way cheapening the construction. While this is dishonest, it is not so dangerous perhaps as the use of inferior materials.

Then, again, the use of steel has brought about changes in the method of manufacture which the small makers



JAMES LAPPAN,

President American Boiler Manufacturers' Association.

have not adopted, and, besides, even those most conversant with steel have yet much to learn as to the effects of heat and other conditions brought about in its use. There are many boiler-makers who claim that good iron is superior to good steel, and it would seem that with old-fogy methods of construction they are right. But there is no doubt that steel is far superior provided it is worked in the proper manner. The advocates of iron, however, will be pleased perhaps to hear that a steel boiler-head which had been subjected to all of the usual tests of elongation, tensile strength, etc., fell to the floor and cracked in two. A manufacturer, in speaking of this, compared a piece of steel to a stick of "taffy," which could be pulled, twisted, and bent, but a sharp blow on the same would snap it into pieces.

At the last meeting of the Boiler Manufacturers' Association a committee was appointed to make actual tests of different methods of riveting, drilling, and punching holes, etc., and will report at the next meeting in Buffalo, and it is likely some new facts will be developed. If it were possible to delegate to the American Boiler Manufacturers' Association the power to fix certain standards of construction and give it the authority to enforce its decisions, we believe that the safety of property and lives would be insured so far as construction is concerned. As matters now stand it is pos sible that there are many boilers made by members of this association which are not constructed in the manner nor of the materials they should be.

This cheapening process, the outcome of close competition, must be stopped and the effort of the association as a body to obtain the passage of laws making it a criminal offense to manufacture, sell, or use inferior materials should meet with the hearty co-operation of the public.

The several committees and all the officers of the American Boiler Manufacturers' Association are all experienced boiler-makers.

The president is Mr. James Lappan, of whom an excellent likeness is shown in the engraving on the page preceding.

Mr. Lappan, who had done so much to bring about the formation of the association, was made the chairman of the first meeting and afterward elected its first president, to which honorable position he was re-elected at the second annual convention this year. Mr. Lappan, who has spent his life in the boiler business, was born in Philadelphia in 1846. Fifteen years later he entered Agnew's old boiler-shop, in Pittsburgh, where he remained eleven years. He was the superintendent of the shop when in 1872, together with two associates, the firm of James Lappan & Co. was organized. Mr. Lappan has now had about thirty years' actual experience in the practical part of boiler-making, and the association could not have selected for its head a more competent man, nor one of greater integrity, and if the same good judgment is shown in the past as has already characterized the meetings of the Boiler Manufacturers' Association, it must take its place as one of the most influential and useful of organizations.

LIMITS OF THE BATTLE-SHIP.

By William Kent, M.E.

WITH the successful trial of Ericsson's *Monitor* twenty-nine years ago there began an evolution in naval armor and armament which appears now to have reached a culminating point in the battle-ships under construction in the United States and in Europe. It appears highly probable that when these ships are finished there will be for many years no attempt either to build larger ships or to equip them with more engine power, thicker armor, or heavier guns. The original *Monitor* was followed by other vessels of the same type, with two turrets and heavier plating, and these by vessels with higher free-board, protected on the sides with still heavier armor. For

twenty years after the close of our war the United States practically ceased building war vessels, but the evolution was rapidly continued by foreign nations, each new vessel being more heavily armored and armed than its predecessor, and thereby making the earlier vessels obsolete as battle-ships. This kind of progress cannot continue indefinitely. Engineering has its limits in the strength of its materials of construction, in the floating power of hulls whose dimensions are limited by the depth of water on the bars in front of harbors, and by the size of practicable docks, and these limits must cause a stopping-point in engineering progress in the direction of mere bulk which cannot be passed until new inventions are made by which this stopping-point may be flanked and new progress made. Over thirty years ago an attempt was made in the *Great Eastern* to pass the then known limits of bulk of steam vessels, and it proved such a failure that with all the resources discovered since that time in the way of steel hulls, compound engines, and the like, the bulk of that vessel still remains beyond the limit of our present experience.

A similar limit seems now to have been reached or even passed in the most recent European battle-ships and guns, and the battle-ship of the near future is not likely to be much if any larger than those now building in the United States, and will probably be smaller than the latest English and Italian vessels.

According to Lord Brassey's paper on the Future Policy of War-ship Building, read March 18 before the Institution of Naval Architects, England is now building 8 vessels of 14,150 tons each ; Germany is building 4 ships of 10,000 tons ; Russia, 2 of 10,000 and 1 of 9000 tons ; France, 3 of 12,000 and 1 of 11,000 tons ; Italy, 4 of 14,000 tons and the United States, 4 of 9000 tons. Even with these large tonnages it is not possible to combine in a single vessel high speed, great thickness of armor, the heaviest guns, great coal-carrying capacity, and sufficient room for crew. One or more of these desirable elements must be sacrificed. If still larger bulk is adopted, in order to combine these requirements, the vessel must be of greater draught, limiting the number of harbors it can enter, or of greater exposed surface, increasing its vulnerability.

But the practical limit does not now appear to be one of mere bulk ; it is found in the limits of the size of the heavier guns. The 100- and 110-ton guns are now confessed to be failures. As Lord Brassey says, the objections to monster guns are the limited endurance, difficulty of manufacture, excessive cost, slowness of fire, length, and hence liability to be struck and possibly disabled, and dependence on hydraulic loading gear too susceptible of injury for the practical purposes of war. The naval advisers of the Admiralty consider that the heaviest gun for battle-ships should not exceed 50 tons. Admiral Scott places the limit at 30 tons.

As for armor, Lord Brassey admits that no practicable thickness of armor is impenetrable, but that twelve inches at the water line is sufficient to give reasonable protection to machinery, boilers, and magazines. As to bulk of vessel, he says, with every increase of displacement the naval architect can give more effective armament, stouter armor, a higher and more enduring speed, more ample coal-supply. On the other hand, if dimensions can be kept within a margin of 10,500 tons as against 14,000, the same tonnage will give eight ships against six. There are few admirals who would not make some sacrifice in individual power for a decided advantage in numbers. He hazards the opinion that the dimensions of the battle-ship of the future should not exceed 10,500 tons, nor should the cost exceed $3,000,000, and that such a vessel armed with four 29-ton guns and an effective minor armament, with a speed of eighteen knots, and much protection by armor, gives a design of as good value for the cost as under existing conditions it seems practicable to secure. Ships of these dimensions offer an advantage, not easily to be measured, over costlier types, in the larger number which can be built for the given expenditure. The opinions of Lord Brassey, thus expressed, seem to be also the opinions of the majority of English naval architects and officers. It is gratifying to learn from these opinions that the new battle-

ships of the United States are fully equal to what is proposed as the battle-ship of the future, and that there is no probability of their becoming obsolete within a few years, as has been the case with the majority of the vessels built by foreign nations in the twenty years after 1862. One of the main arguments advanced against building battle-ships in this country has been that they would soon become obsolete. This argument has probably now no foundation, and we may be reasonably sure that the 9000- or 10,000-ton vessel will retain many years the position of the first-class vessel.

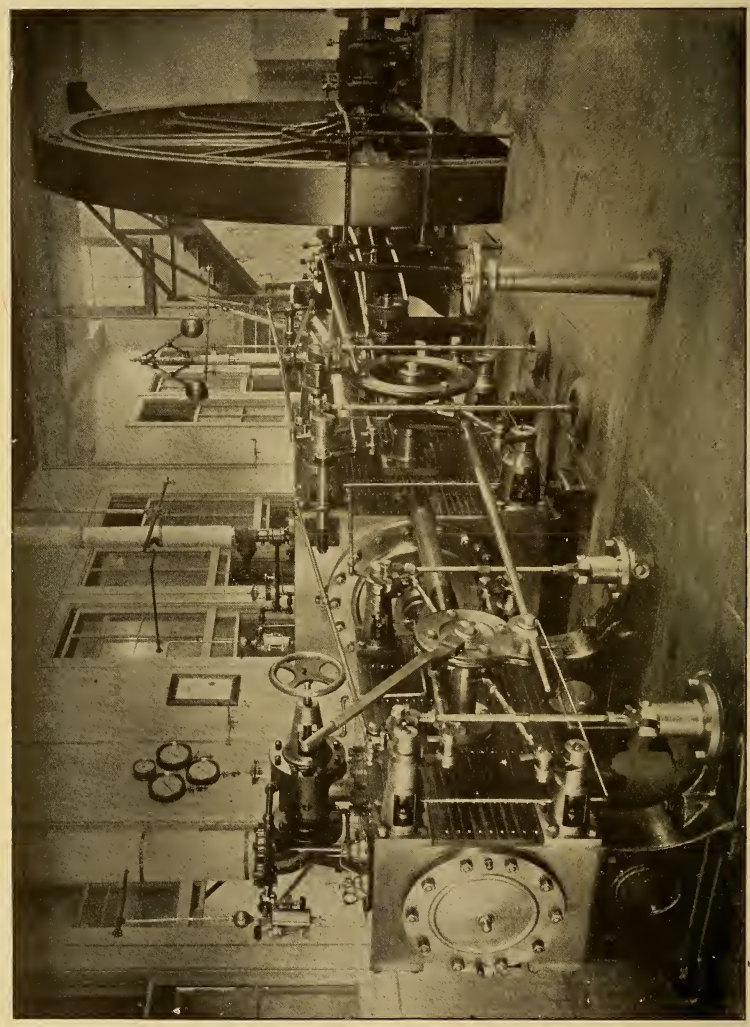
The idea has been advanced by some writers that because no armor which can be floated can be made impenetrable, therefore armor for vessels will some day be dispensed with, just as armor for the human body was dispensed with after the invention of gunpowder and the use of musket-balls which could penetrate it. But the conditions are altogether different. A man cannot carry armor heavy enough to resist a rifle-ball, while a vessel can carry armor heavy enough to resist all but the heaviest guns ; without any armor the largest vessel would be sunk in a few minutes by the sweeping fire of a rapid-firing gun of the Hotchkiss or similar pattern. Armor of some kind is therefore a necessity, and a compromise must be made between a light armor of moderate resisting powers and armor too heavy to be carried. Twelve inches of nickel steel, or steel of other kind with a hard face, is probably the best compromise under the circumstances.

The battle-ship is defined as a vessel which can go anywhere and do anything. It is not possible for it, however, to go anywhere at the highest speed attained by vessels of another class, nor to do anything in the highest degree in which anything can be done, as to carry at the same time the heaviest possible armor and the heaviest possible guns. She must leave the highest speed to the protected cruiser and commerce destroyer, and the heaviest armor and guns to the slow-speed coast-defense vessel. She must have coal-carrying capacity to enable her to go anywhere, and fighting power enough to never need to run away. These conditions are all met in our own new battle-ships, and we therefore may consider them a fixed type.

In the second class of vessel, the protected cruiser and commerce destroyer, we are also abreast of the world. The limits for many years to come are probably reached in this class, also in the new No. 12 cruiser, the latest design of our government, which is intended to have a speed of twenty-one knots, and be able to chase and capture vessels like the *City of Paris* and the *Teutonic*.

In the other class of war-ship, however, the coast defense vessel, neither the United States nor any foreign power has yet approached the probable limits. The duty of this vessel should be to stay at the outer entrance to a harbor, and prevent the entrance of a foreign battle-ship. She should have the largest guns that can be carried and fired without destroying themselves or the ship, and armor that would resist a steady fire from a fleet of battle-ships just as our monitors during the war resisted the fire of the old smooth-bore cast-iron guns. Such a vessel requires but slow speed, and little coal capacity, therefore nearly all her floating power can be devoted to carrying armor and guns. One or two vessels of this class stationed at Sandy Hook, together with a steel fort on the Hook, would be the surest defense of the port of New York. It is to be hoped that as our government has made a good beginning in the building of the two classes of battle-ships and cruisers, in each case building close to the practical limits of good construction, it will soon make an attempt to approach the limit which has never yet been reached of a good coast-defense vessel.

THE Connellsville *Courier* says the greatest engineering feat in the history of anthracite coal-mining in Pennsylvania is about to begin. It is the commencement of what is called the Jeddo tunnel, which will be driven for the purpose of draining the flooded mines of Jeddo and Harleigh. It will be constructed from Butler Valley to the bottom of Ebervale mammoth vein, a distance of three miles, through solid rock, to be eight feet square in the clear.



COMPOUND CORLISS ENGINE AT MONTAGUE STREET CABLE-POWER HOUSE, BROOKLYN, N. Y. BUILT BY C. & G. COOPER & CO., MT. VERNON, O.

A NEW CABLE PLANT.

An engine which has attracted considerable attention among engineers has been operating the Montague Street cable road in Brooklyn since July 20.

This engine, of which an illustration is shown on the page opposite, was built by C. and G. Cooper & Co., of Mt. Vernon, O., and was installed and put in operation under the direction of Robert Gillham, C.E. It is a right-hand tandem compound condensing Corliss engine, 16 x 30 x 42". The fly-wheel is 20 feet in diameter, made in segments, and weighing 50,000 pounds.

The shaft is 12 inches in the bearings, 14½ in the center, and rests in an adjustable outboard bearing having a heavy sole-plate. Outside the outboard bearing is the coupling by which it is attached to the winding machinery.

The bedplate and main parts are those of the regular 24 x 42' Cooper engine.

The engine is furnished with a jet condenser operated from the crank-pin. Condensing water is drawn from 12 to 2-inch driven wells, which has been found in ample supply.

The piping between cylinders and condenser is so arranged that the engine may be run either compound condensing or compound non-condensing. The exhaust from the high-pressure cylinder may also be cut off from the low-pressure cylinder and passed direct to the condenser or allowed to escape into the atmosphere.

A by-pipe leads from the main steam pipe to low-pressure cylinder, so that live steam may be used in starting up. The engine has the characteristics of the Cooper high-pressure engine, as exemplified in the flaring base of the main journal, the broad, flat sides, central cross-head pin, the massive cross-head, and the rocking hook release-gear.

The dash pots are of the form designed for the Cooper cable and electric railway engines, in which the amount of vacuum and cushion may be regulated to suit the widest variation in load.

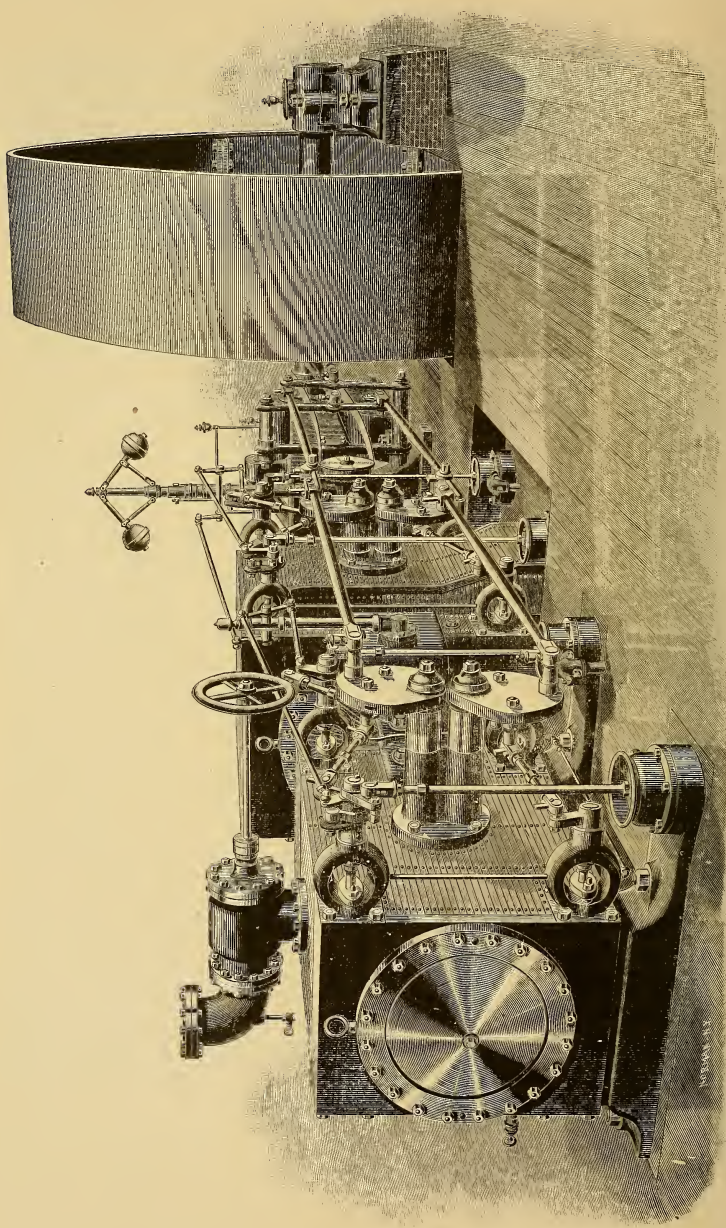
The valve-gear of both cylinders is operated from a single eccentric, and the governor is of the usual Corliss type. The lubrication is entirely automatic. The engine has been running about fifteen hours per day (except Sunday) since July 20 with perfect smoothness without heating of a single part.

The boilers for this plant were made by the National Water Tube Boiler Company, of New Brunswick, N. J.

EXPERIMENTS WITH IRON.

A number of gentlemen who are connected with the manufacture of iron and steel, including two manufacturers from Australia, assembled at Messrs. H. Young & Company's iron foundry, Eccleston Street, Pimlico, one day lately, says the *Engineers' Gazette*, of London, to witness an experiment with a view to the production of a superior from an inferior quality of iron by the aid of a new flux which has been named stephanite, after its inventor, the late Mr. Stephan. The point involved is the addition of aluminum to iron. By adding aluminum to the charge of iron in the cupola in the ordinary way it is found that the blast carries it away and that the admixture is not effected. By adding it to the molten charge of iron in the ladle stirrers have to be employed, and this does not affect a uniform admixture of the aluminum with the iron, and a homogeneous metal does not result; it is merely a mechanical compound.

What Mr. Stephan did was to take certain proportions of alumina, emery, and lime, to incorporate them together, and to press them into briquettes. These briquettes are added to the charge of iron and coke in the cupola in the proportion of 80 pounds of stephanite flux to one ton of iron. The action which is then said to take place is that the high temperature of the furnace converts the alumina into metallic aluminum gases, which are absorbed by the molten metal, and thus form a chemical compound as contradistinguished from a merely mechanical one. It is claimed for the flux that it acts as a clearing agent on the



TANDEM COMPOUND CORLISS ENGINE. BUILT BY THE FRICK COMPANY, ENGINEERS, WAYNESBORO, PA.

See page 67.

metal, and separates every particle of it from the slag ; that the molten metal leaves the furnace in a highly fluid condition, and that consequently better castings are obtainable and blow-holes are avoided.

At the demonstration at Messrs. Young's works a cupola was charged with three tons of very poor cast-iron scrap, with the prescribed addition of 240 pounds of stephanite. The whole of Messrs. Young's large foundry was placed at the disposal of the Stephanite Company, of Blomfield House, London Wall, who are introducing the invention. Messrs. Young having previously satisfied themselves of the *bona fide* and practical character of the invention, resolved on having the whole of their castings for that day, large and small, run from the new metal. The castings were so run, and the great fluidity of the metal was seen from its behavior in the ladles, into which it was run from the cupola. When sufficiently set, two castings were taken from their molds, and, while at cherry-red heat, plunged into cold water.

This was a crucial test to begin with, as ordinary cast-iron similarly treated would either have flown to pieces at once or as soon as it received a blow. Here it did neither, for after being quenched one of the castings was broken in half, and showed a very good steely fracture. The file was applied to these castings, but failed to make more than a mere surface impression on them except at one point of one of them—the end—which, in common with ordinary castings, was found to be somewhat softer than the center of the piece. One-half of the casting was then heated in a blacksmith's forge and cooled in the air. It was then found to be soft and amenable to the file. The same piece was then reheated, and when at a cherry-red was plunged again into cold water. After cooling, on again being tried with the file it was found to resist it most successfully. The opinion of those qualified to give one was that it was a most remarkable result, and that the invention appeared to be one capable of very wide application. So far as the trials went, they demonstrated the production of what may be considered as a new metal.

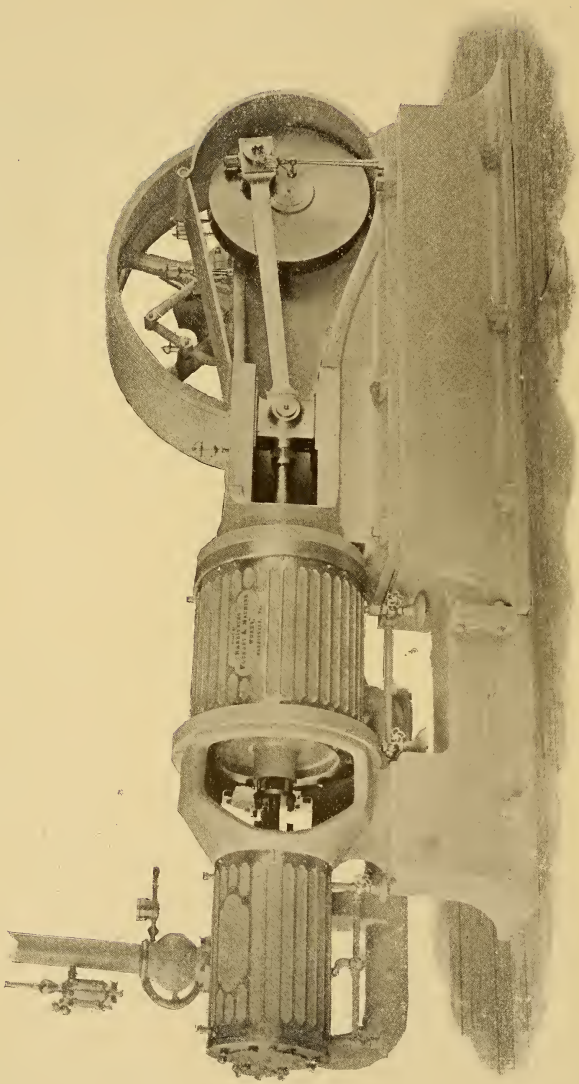
NEW TANDEM COMPOUND CORLISS ENGINE.

On the opposite page is an engraving of a tandem compound Corliss engine which was built by the Frick Company, engineers, Waynesboro, Pa. The valve-gear is of the well-known Corliss type, with constant lever disengaging motion. One governor controls steam valves on both high- and low-pressure cylinders. The wrist-plate motion is driven by two eccentrics, making independent actuation for steam and exhaust-valves, and is known as the long-range cut-off. The engine is designed for electric railway and cable work where the variation of the loads is very great.

Low-pressure cylinder is 44 inches diameter, high-pressure 30 inches diameter, fly-wheel 25 feet diameter, 6 feet face, weight 50 tons. Connection is had between the high- and low-pressure cylinders by means of receiver-pipe, which connects with a flat passage secured on the side of the low-pressure cylinder leading to steam chest. The engine illustrated has a nominal capacity of 750 horse power. The arrangement of the valve-gear is well understood by reference to the drawing. Under severe conditions of actual practice the regulation shows all that could be desired.

HARRISBURG IDE TANDEM COMPOUND ENGINE.

On the page opposite is shown an illustration of a tandem compound engine recently built by the Harrisburg Foundry and Machine Works. As may be seen by reference to the engraving, the construction is such that the low-pressure cylinder-head can be slipped sufficiently far to allow the examination of the low-pressure piston without breaking any connection, which saves



NEW TANDEM COMPOUND IDE ENGINE. BUILT BY HARRISBURG FOUNDRY AND MACHINE WORKS.

See page 67.

much time and labor if it is found necessary to inspect the piston or low-pressure cylinder. The connections, as will be observed between the high-pressure and low-pressure cylinder, are provided with a bracket which is planed and has a tongue on the bottom working in a corresponding groove of the base. It is not bolted fast, but is free to expand in change of temperature without getting the cylinders out of alignment. It also affords such a complete support to the cylinders as to avoid any swaying when engines are working up to their capacity. These engines can be provided with self-contained cast-iron base, as shown in the engraving, for all sizes up to and including 200 horse power. The engines are made very heavy in all of the parts, allowing liberal bearing and journal surface working engine to its maximum capacity. The valves for both the high- and low-pressure cylinders are actuated by one eccentric and controlled by an automatic governor which is very sensitive and gives close regulations. Both valves are accessible, all complication avoided, and necessarily makes the engine very advantageous for general electric-light and railway purposes, as well as for all general power purposes.

The Foundry and Machine Works are prepared to furnish these engines in sizes ranging from 75 to 400 horse power.

THE NEW BALL COMPOUND ENGINES.

On the following pages are printed illustrations of a cross compound engine and also a tandem compound which the Ball & Wood Company have just completed in their shops at Elizabeth, N. J. The general design and construction of these engines is the same as those which have been built under the supervision of Mr. F. H. Ball, the inventor, at the works of the first company he formed, in Erie, Pa.

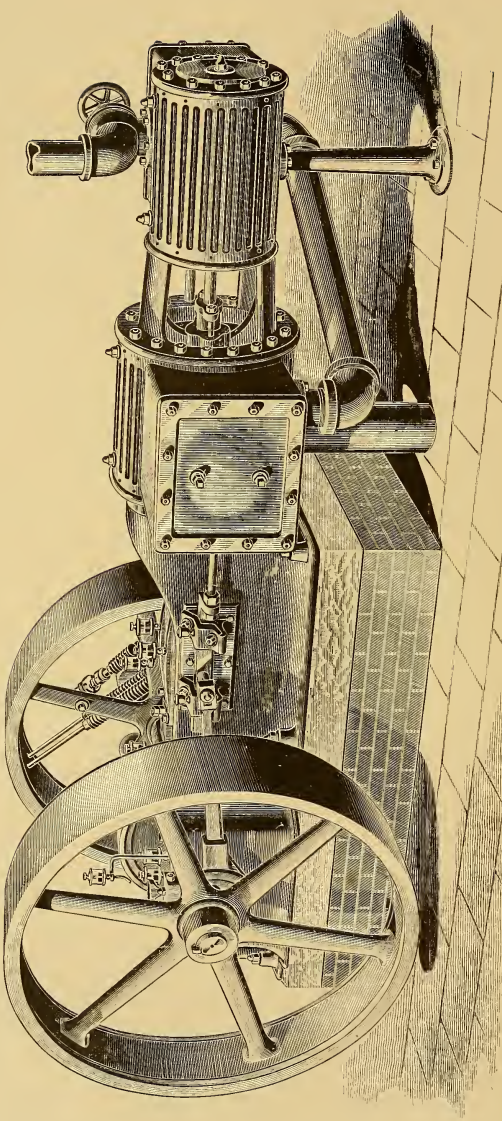
The illustration of the cross compound represents an engine just built for the Newark Electric Light Company, of Newark. The size of the low-pressure cylinder is 13 inches and the high-pressure 25 inches, with a stroke of 16 inches. The builders claim that it will economically produce 300 horse power.

The tandem compound was built for W. H. Day, Boston. Its high-pressure cylinder is 10 inches, low-pressure 18 inches, and 12 inch stroke.

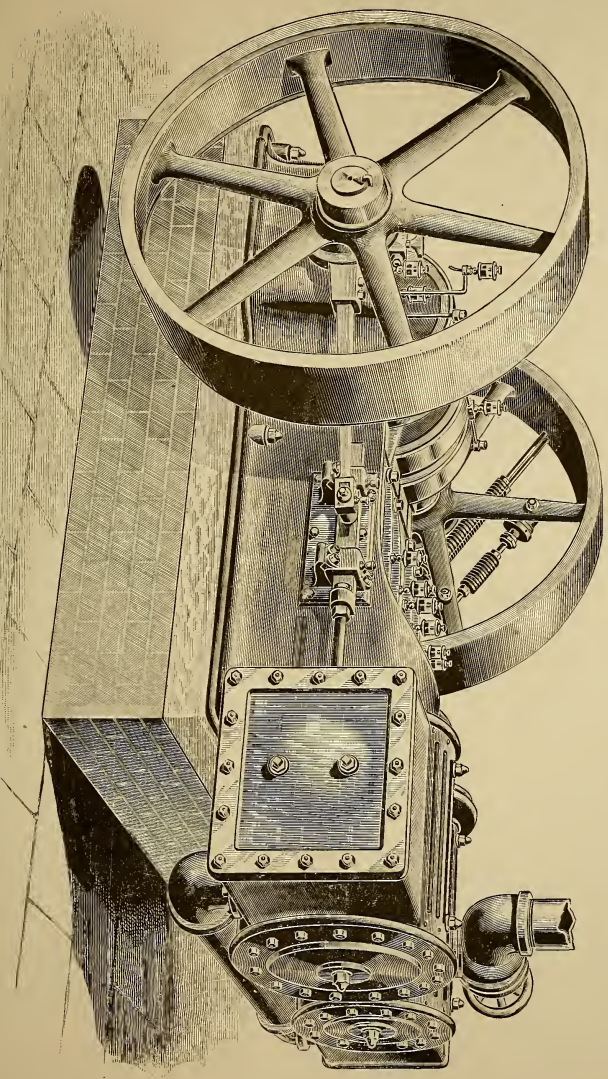
Both of these engines are regular sizes which the Ball & Wood Company are building. They are now completing three single engines of 150 horse power each for the Edison Electric Light Company, at Patterson, N. J., as well as several for the Edison General Company, of Trenton, N. J., the West End Electric Railway, at Lancaster, Pa., and Seauquoit Silk Mfg. Company, Scranton, Pa.

HOLLOW FORGING.

According to an account given of a new German process in metallurgy, hollow forgings in iron or steel are made from solid blocks of red-hot or white-hot iron or steel, says the New York *Sun*. To produce a hollow cylinder, a piece of hot square metal is taken, the cross-section of which, diagonally measured, corresponds to the diameter of the hollow cylinder to be produced, and a pointed core-bar is then driven into the metal by means of a hammer or press, the lid of the matrix forming a guide for the core-bar. When desired, the matrices may be formed with jackets in which circulates a cooling medium. The metal is thus forced to fill the cylindrical matrix, and has an opening through its center in the direction of its length. Hollow prismatic bodies may be produced in a similar manner to that which has been described, an important condition being stated to pertain to all cases, namely: that the metal to be operated upon shall be truly centered by the matrix. For hollow bodies of unusual length two core-bars may be employed, entered into the metal from opposite ends. The frames of steam hammers may form the guide to the matrix.

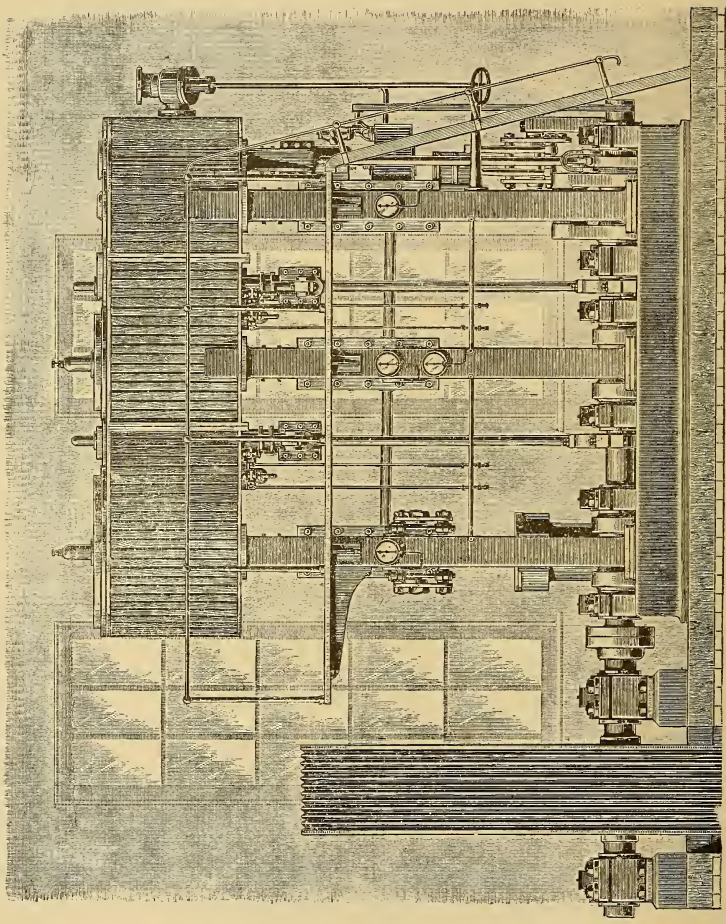


TANDEM COMPOUND ENGINE. BUILT BY THE HALL & WOOD CO., NEW YORK.
See page 69.

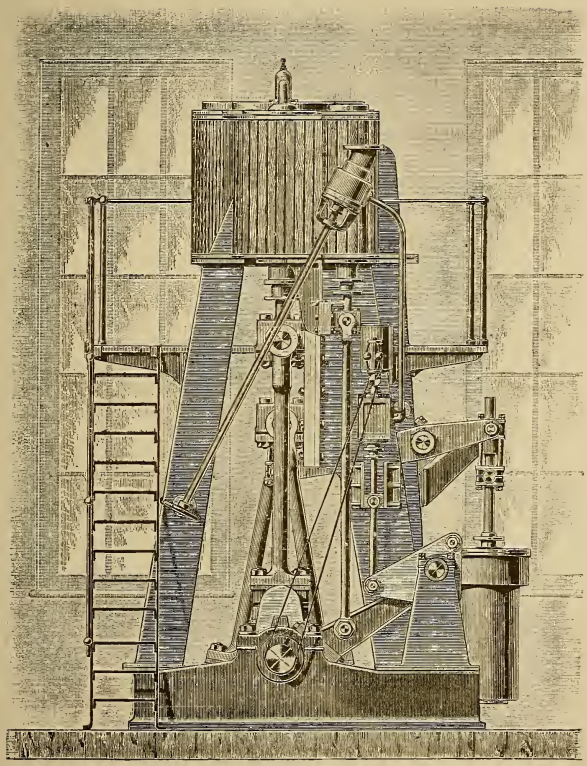


CROSS COMPOUND ENGINE. BUILT BY THE BALL & WOOD CO., NEW YORK.

See page 69.



TRIPLE-EXPANSION INVERTED CYLINDER ENGINE. BUILT BY ERNEST SCOTT & CO., NEWCASTLE-ON-TYNE.
See page 35.



END VIEW TRIPLE-EXPANSION VERTICAL ENGINE. BUILT BY ERNEST SCOTT & CO., NEWCASTLE-ON-TYNE.

See page 35.

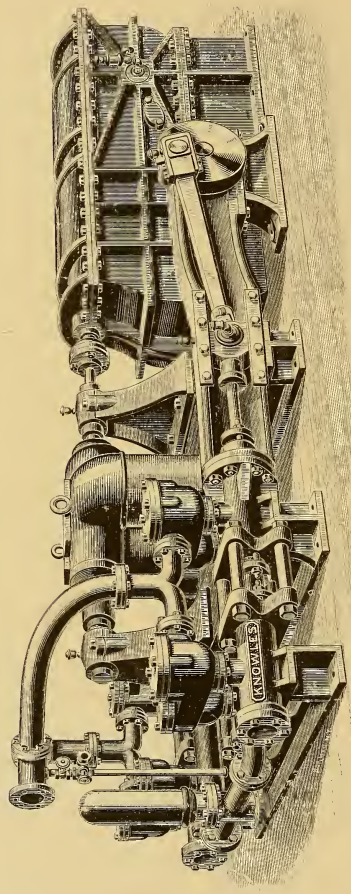


FIG. 1.—ELECTRIC PUMP, BUILT FOR HAMILTON ORE COMPANY.

ELECTRICITY APPLIED TO PUMPING MACHINERY.

By F. Meriam Wheeler, M.E.

WHILE the use of electricity as a motive power for pumping purposes is not entirely new, its application to heavy pumping machinery, such as is used in mines, water-works, or for elevators, has been only very recently dedeloped, and though much interesting information could be written on its various uses, the writer will confine himself in this article to the particulars of its adoption in connection with the pumping of mines and for water-works purposes.

The readers of CASSIER'S MAGAZINE who have ever been in the shaft of a deep mine can readily see what a transformation there must be from the Cornish pumping-engine, with its enormous amount of material,—huge pump-rods creaking with friction at every bearing point and shaking in every part with each pulsation of the engine; the great beams rising and falling at each stroke; the many column-pipes for the different "gangs" of pumps. The space occupied is great, and the lost motion and waste of power are enormous.

With a lift of 1000 feet, there would be required with an improved Cornish pump three or four lifts, or, in other words, three or four sets of pumps, all driven by an engine on the surface, and as these pumps are single-acting, the discharge of water is therefore intermittent, so that very large pipes, which are usually the same diameter as the plungers of the pumps, are required. Besides needing a great amount of space, all this mass of material must be carefully watched in order to keep it in working order.

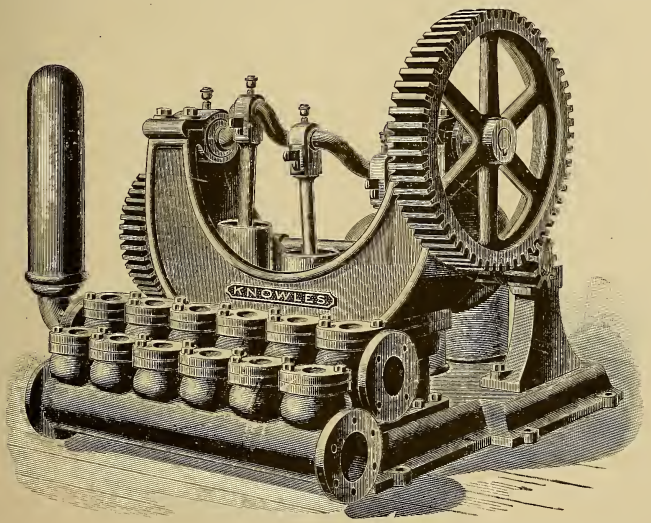


FIG. 5.—VERTICAL ELECTRIC PUMP FOR ELEVATORS.

Electricity is changing all this. The immense pump-rods give way to two delicate threads of metal, and the large discharge-pipes are superseded by those

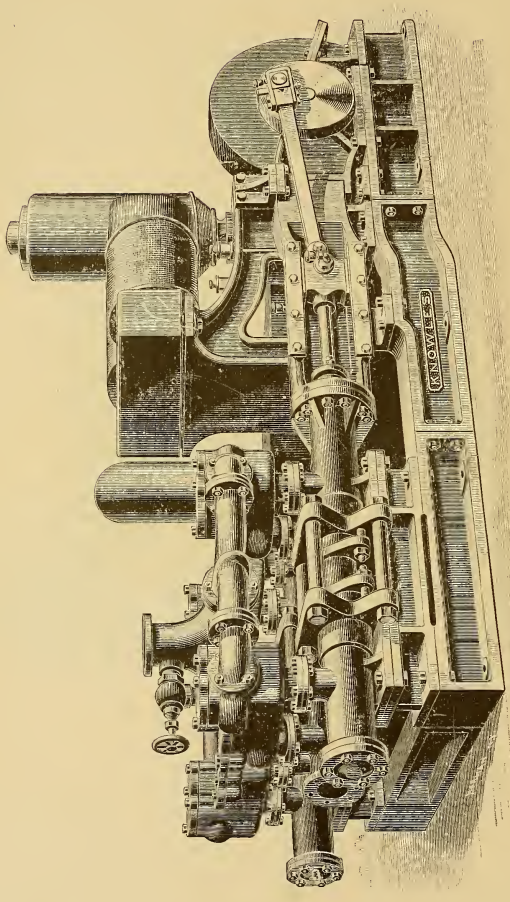


FIG. 2.—ELECTRIC PUMP FOR POOR MAN'S MINE.

of quarter the diameter, yet, as the electric pump is double-acting, it is sufficiently large, and there is a continuous flow of water.

Fig. 1 represents an electric pump which was built for the Hamilton Ore Company and has a capacity of 200 gallons per minute when pumping in one direct lift to a vertical height of nearly 1500 feet. The motor is of the improved Thomson-Van Depoele type, and is

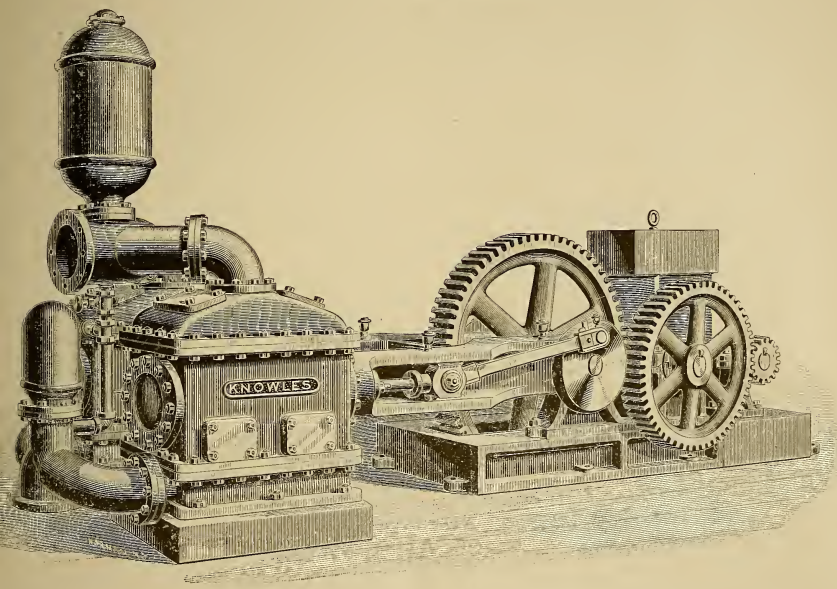


FIG. 3.—ELECTRIC PUMPING-ENGINE FOR WATER-WORKS.

arranged with right and left-hand thread on gearing so as to take up the thrust. The entire gearing is encased in a tight chamber holding a quantity of oil, so that the gears are always submerged in lubricating material. The friction is absorbed in the gearing without any end thrust or "step" by a very cleverly designed arrangement. The water-plungers are cast of gun-metal bronze and are exceedingly hard, so as to resist cutting from gritty water. The water-valves are encased in special castings (called pots) in which are grouped valves of special material and construction. The intermediate mechanism between the electric motor and the pump is made very strong and provided with means for taking up wear and preventing lost motion, so that such a pump is more easily taken care of than one run by steam.

Another large mine-pump, perhaps the largest in the world up to date, which was built for the PoorMan Mine, is shown in Fig. 2. This electric pumping-engine has a capacity of 500 gallons per minute, lifting that amount of water in one single lift of nearly a thousand feet. In this case the motor is the Edison type of vertical design arranged with "steps" for taking up thrust. The connection between the motor and pump is by single worm-gearing, which is encased in a tight chamber holding lubricating oil, and the general design of the pump end of the machine is the same as that shown in Fig. 1, with the exception of the "pots" or valve-chambers, which are somewhat different in form.

While electrically-driven pumps for mines are a success, other industries are

also awakening to the advantages which electricity gives in this direction. In many small towns there are electric plants but no water-works, and with such a pump the power could be used from stations which could be miles from the source of water-supply. Fig. 3 illustrates an electric motor applied to a duplex water-works pumping-engine. In this case the motor is of the Edison vertical type, arranged with insulated pinion, etc. The spur-gearing is cut on a new principle ensuring quiet running and a minimum wear. The water end of the machine is the usual water-works type, having composition plungers working through composition sleeves. The suction-valves being placed below and the discharge-valves above the plungers, gives the room necessary for a very large amount of valve area and water passages. This reduces the friction of the water as it passes through the pump to a minimum. There is a connection between the discharge of the pump (immediately under the air-chamber) and the suction-chamber with a gate-valve on same ; the object of this arrangement is that when starting up the pumping-engine the pressure on the pump can be taken off the valves by letting the water flow back into the suction. The check-valve on the discharge nozzle, which is necessary to this arrangement, is not shown by the illustration.

One of the largest fields for electric pumps is for passenger and freight elevators, and for such use the type of pump as shown by Figs. 4 or 5 is being used with success. The former shows the pump placed horizontally, while the latter shows it arranged vertically. In each case they are single-acting pumps, plungers being made of composition. These pumps are driven by Thomson-Houston motors, and the intermediate mechanism is carefully cut gearing. The convenient hand-holes on the pumps admit of ready access to the valve,—in fact, every part of the machinery is easily got at when necessary. These are important features, because on the thorough maintenance of the machine depends so much.

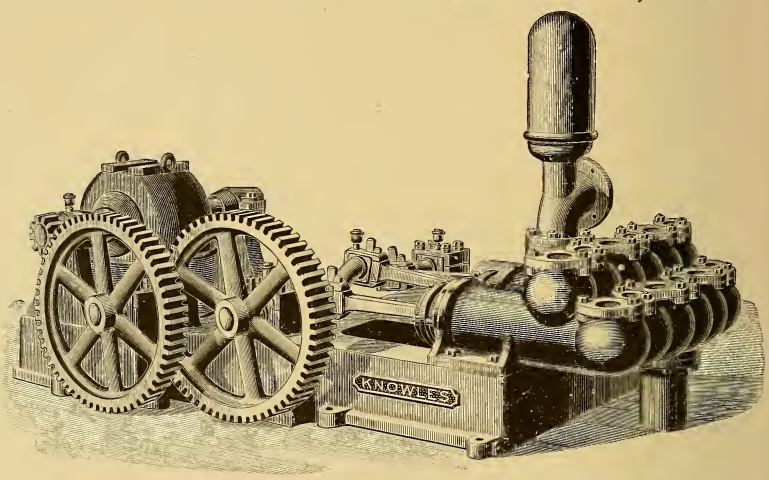


FIG. 4.—HORIZONTAL ELECTRIC PUMP FOR ELEVATORS.

In the limited space at my disposal it is impossible to give other illustrations of the different applications of electricity to pumping-engines. It is hardly necessary to say that the day is very near at hand when many kinds of pumping machinery now driven by steam and other methods will be replaced by those

electrically driven. As an illustration, there is already under discussion a plan to substitute them in naval ships for those now driven by steam. The saving of piping alone (of which there are many thousand feet) would be a great advantage in any sea-going vessel, particularly the high-powered cruisers, where the room is very limited.

THE FLOW OF WATER THROUGH PIPES.*

IT is curious that such an important practical problem, and apparently such a simple one as the head required to force water through a length of piping, has never been reduced to a perfectly satisfactory formula. At very low velocities it has long been known that the friction between a fluid and a solid body varied directly as the relative velocity of the two, but as the velocity is increased, this simple law no longer holds, and the resistance increases as some higher power of the velocity than the first. It had long ago been suggested that the reason for this increase in resistance was due to the formation of eddies, but it was not till 1883 that Professor Osborne Reynolds rendered these eddies visible in connection with his remarkable paper, entitled "An Experimental Investigation of the Circumstances which determine whether the motion of Water shall be Direct or Sinuous, and of the Law of Resistance in Parallel Channels."

In these experiments water was caused to flow through a length of glass tubing very uniform in diameter. In the center of the entrance to this tube, which was coned to avoid eddying at that point, was placed a fine jet, through which flowed a thin thread of colored water, which passed through the main tube with the rest of the water flowing through it, as a beautiful straight thread of liquid, which remained perfectly distinct from the surrounding water. As the velocity of flow through the tube, however, was increased, this thread began to "wobble," and finally, on a certain critical velocity being reached, dependent on the diameter of the tube and the temperature of the water, it broke up into eddies, mixing with and becoming indistinguishable from the general mass of water in the tube. For some time before this critical velocity was reached, however, the non-eddying motion was unstable for large disturbances. A remarkable feature of the experiments was the suddenness with which the non-eddying motion changed into the eddying. It should be stated that the eddies only formed at some distance from the entrance to the tube, getting nearer to the entrance as the velocity increased, but never quite reaching it. Thus it is possible to have in the same pipe a length in which the motion is non-eddying, followed by a length in which it is wholly eddying, and hence the loss of head on two consecutive lengths of pipe need not necessarily be the same. When one further takes into consideration the fact that the resistance also depends on the temperature of the fluid, the difficulty of the problem is considerably increased.

In spite of this, however, there is little doubt but that a thoroughly practical and accurate formula would have been arrived at ere this, were it not for the fact that the resistance varies very largely with the degree of roughness of the pipe surface, and there has as yet been no method proposed for measuring degrees of roughness. That is to say, it is impossible to specify any given surface as twice as rough as another, and thus there appears to be no possibility of discovering the way in which an increase in the degree of roughness changes the law of flow. The best that can be done is to describe the surface, as glass, tin, new cast-iron, etc., and this course is that which has been universally adopted. But as two surfaces of new cast-iron, for instance, may be of a very different degree of roughness,

* *Engineering*, London.

discrepancies in the results of experiments are only to be expected. Hence the most we can hope for is a formula which shall give results which, on the average, will be on the safe side.

As to the form of such a formula it is evident that the velocity will vanish with the head producing it, and further experience shows that the head required for a given velocity decreases as the diameter increases, hence the most simple form of such a formula would be

$$\frac{h}{l} = \frac{m}{d^x} \cdot \frac{v^n}{2g},$$

where h = the head-producing flow in feet, l = length of pipe in feet, v = velocity in feet per second, and d = diameter of the pipe in feet, and m a coefficient. This form was arrived at by Hagen, a Prussian engineer, in 1854. A precisely similar form was also proposed by Professor Osborne Reynolds as the result of his experiments already mentioned.

Professor Unwin has calculated the values of the coefficients m, n, and x from the results of experiments on actual pipes. He gives for new cast-iron pipe: $m = .0215$, $x = 1.168$, $n = 1.95$, and for cleaned cast-iron pipe, $m = 0.243$, $x = 1.168$, and $n = 2.00$.

Darcy, who was the first to make experiments on a practical scale, deduced from his results the well-known formula

$$\frac{h}{l} = \zeta \frac{v^2}{2g} \cdot \frac{1}{d},$$

where $g = 32,2$, ζ = a coefficient, and the other letters have their previous significations.

ζ is not a constant, but varies with the diameter of the pipe being found by the relation

$$\zeta = 0.02\left(1 + \frac{1}{12.d}\right).$$

This formula is satisfactory enough for ordinary pipes, but gives inaccurate results for pipes with very smooth surfaces. For such pipes Mr. Weston has in a paper read before the American Society of Civil Engineers proposed the formula

$$\zeta = 0.0126 + \frac{0.0315 - 0.005.d}{\sqrt{v}},$$

where d is the diameter of the pipe in feet.

From Mr. Weston's curves it appears that this formula gives very accurately the mean of the results of the experiments of different observers on such pipes. It is, however, very complicated, as in general the velocity v is quite unknown, and must be approximated to, and it is almost certainly inaccurate in form, as it is difficult to believe that any part of the formula for the head-producing flow should be negative.

Mr. Weston has also examined the case of pipes with medium rough surfaces, and for such has not been able to find any superior to Darcy's, whilst for old encrusted cast-iron pipes he has been able to find no satisfactory formula whatever. This last result is only natural, as the roughness and real diameter of such pipes may vary within very wide limits, and the results obtained by different experimenters are naturally discordant. Mr. Weston gives the formula for ζ as

$$\zeta = 0.019892 + \frac{0.00166573}{d},$$

which is practically the same as that we give above, whilst not nearly so convenient to work with arithmetically.

In a large proportion of the cases which arise in practice, however, the information sought is the diameter necessary to supply a given quantity of water under a given head. The diameter is very commonly taken to vary as the two-fifth power of the discharge. This is almost certainly too large. Hagen's formula with Professor Unwin's coefficients give

$$d = c\left(\frac{Q}{\left(\frac{h}{l}\right)^{\frac{1}{2}}}\right)^{.387},$$

where $c = .239$ when d and Q are in feet and cubic feet per second, and $c = 5.84$ when d and Q are in inches and gallons per second.

Mr. Thrupp, who has also examined the results of many experiments, has proposed a formula which makes d vary as the .383 power of the discharge, and

M. Vallot, a French engineer, has proposed the following rule as practically accurate, viz :

$$d = c\left(\frac{Q}{\left(\frac{h}{l}\right)^{\frac{1}{2}}}\right)^{\frac{3}{8}}.$$

The index here corresponds very closely with that in the formula deduced from Professor Unwin's figures, which is very nearly $\frac{31}{80}$. M. Vallot, however, uses a larger coefficient than that given above, so as to be on the safe side.

There is thus a consensus of opinion among recent investigators that the diameter for a given discharge increases at a less rapid rate than the two-fifth power of the head.

HOT AIR AND STEAM FOR POWER.

THE English journals have recently been describing some experiments with an engine which had been specially fitted to use in its cylinder certain proportions of steam and hot air. It is described, not as an invention, but as a discovery. Without having the definite data as to the experiments, the description which we have abstracted from *Hardware Trade Journal* leads us to believe that the arrangement is very much like that of an engine for which a patent was granted by the United States Patent Office some thirty years ago to James M. Storm, of New York.

Mr. Storm built an engine having a cylinder arranged for the combined use of hot air and steam which was set up in a printing office, where it was used for many years, but for some reason no further efforts were made to improve the idea. Regarding the experiment recently made, the journal mentioned says:

"It is well known that the practical efficiency of the steam engine is very far below the standard which theory correctly sets up for it. This inefficiency means a serious loss of power in relation to fuel consumed. In other words, the mechanical work done by a pound of coal in our best engines—that is, by the conversion of heat into motion—is greatly less than theory tells us it should be. The steam engine is, therefore, a more or less uneconomical motor, but such is its value that we have to accept its services on the best terms it will allow us to make with it. It is true that great strides have been made of late years in increasing the economy of the steam engine, and of the boiler also. Furnaces have been improved, the heating surfaces of boilers have been improved and increased; the engine has been improved in many of its details, and the utmost has been done to get full value out of the steam, and therefore out of the coal, by compounding, triplicating, and quadrupling it. But for all this its present economy is often all but comparative, and at the best its efficiency is very low. It has long been seen that what is required is some radical change, not so much in the construction of the engine, perhaps, as in the fluid by which its parts are put in motion. To this end it has been proposed to supersede steam by various gases or to add them to it and use them in a mixed form. Air has found much favor with inventors, and there have been times when the use of combined air and steam appeared to be a practical method of improving the steam engine. But, apart from gas engines and hot-air engines pure and simple, down to the present time there has been no record of commercial, or even practical, success having attended the introduction of air in any way into the steam engine. The study of this subject, however, has proved very attractive, and has led not a few to follow it up in the hope of achieving that success which was reasonably to be expected from the principle involved if rightly understood, and its investigation correctly pursued. Among others who have taken a deep practical interest in the question of the use of combined air and steam in the

engine is Mr. Edward Field, C.E., who has been well known for many years past in connection with the steam boiler bearing his name. His improvement was a great step in advance in the steam boiler, but it is probable that it will be found that he has now made a far greater advance in the engine by increasing its efficiency and economy in a very remarkable degree. And what he has really done partakes rather of the nature of a discovery than of an invention. Put in a few plain words, Mr. Field produces the volume of mixed gases under pressure necessary for performing a given amount of work in an engine with the use of only from from 12 to 20 per cent. of the quantity of steam which would be used in the same engine to perform the same amount of work. This volume of mixed gases consists of a small volume of steam introduced into a large volume of heated air. Whatever of invention there is in the present connection relates to the apparatus by means of which the discovery is utilized in practice. This apparatus consists of two portions—namely, the experimental, whereby Mr. Field demonstrates the principles of his discovery, and the practical, by which he illustrates the application of those principles in doing work. This apparatus of both kinds was recently exhibited in operation with results which fully support all that Mr. Field claims in respect of the principle. The experimental apparatus consists of two measuring chambers of different capacities and a working cylinder having a weighted piston. In order to prevent condensation or loss of heat a high temperature is maintained in each of the chambers. In order to render the experiments comparative, steam was first admitted to both of the measuring chambers at a pressure of 60 pounds per square inch. This steam, which represented twenty volumes, was then admitted to the working cylinder, and it raised the piston with a load of 171 pounds to a height of 5½ inches. The experiment was repeated, when the piston was only raised 4¾ inches. The smaller of the two chambers was then half filled with steam at 60-pound pressure, and the larger chamber with heated air at a temperature of 400 degrees Fahr., which is about the temperature required in practice and at atmospheric pressure as shown by the respective gages. The proportions were two of steam and sixteen of heated air, and upon the admission of the steam to the air the gages on both chambers instantly showed a pressure of 60 pounds per square inch. Upon the mixture of steam and air being admitted to the cylinder, the weighted piston was rapidly driven up 7½ inches, which was as high as it could reach, and represented the stroke of the piston within the cylinder. Upon the experiment being repeated, the weighted piston rose much more rapidly, giving the cylinder a violent blow. A number of other experiments were made with similar results, and as a whole clearly demonstrated that the twenty volumes of steam failed to do the work that two volumes of steam combined with sixteen volumes of heated air did. They further showed that the best results were obtained with these proportions of the two fluids, and these are about the proportions which Mr. Field employs in practice. It should be observed that in practice the air is heated at little or no cost by the waste heat which in an ordinary engine escapes. The principles here involved have been put in practice by Mr. Field in a portable engine, which, however, has several drawbacks in consequence of the mixing chambers having to be superadded to the existing engine works. These chambers are mounted on the top of the engine cylinder, and there is a chamber for each end of the cylinder. Each of these chambers in turn receives its charge of heated air, into which is delivered a proportionate charge of steam. The mixture is delivered from each chamber alternately to the front and the back end of the cylinder, causing the out-strokes and the in-strokes of the piston in succession. The engine was first run with steam alone and without a load. It was then run with combined steam and heated air in about the proportions previously stated. The conditions under which this run was made were the same as in the previous run, and the same observations were taken. It may be mentioned that the temperature in the air-chamber should not be less than 400 degrees Fahr. for the proper development of the advantages of the system. As a

matter of fact, the air temperature during the engine trials was not higher than 300 degrees, but was generally much lower, owing to draughts and to the inefficient construction of the heating apparatus. On comparing the results of the two engine runs, made respectively with pure steam and with combined steam and heated air, it was found that there was an absolute gain of 44 per cent. in favor of the Field system as against ordinary steam.

"The system, as well as the experimental apparatus, has been independently tested by three engineers, namely: Mr. Collett Homersham, C.E., Mr. D. K. Clark, C.E., and Mr. Perry F. Nursey, C.E., each of whose reports substantiates this economy and points to still higher results with a larger engine properly and efficiently fitted with the necessary adjuncts for working upon Mr. Field's principle." It is to be hoped that Mr. Field's experiments will not be lost in obscurity as were those of Mr. Storm.

HOT BLAST FURNACE.

An English manufacturer has lately brought forward an improved hot-blast furnace, the method employed being to use the heat derived from the furnace for heating the air blown into it to smelt the contents. The mode of carrying out this plan is by letting into the brickwork, on all sides of the furnace, several chambers immediately over the tuyere pipes, within about three inches of the inner face of the furnace, says the New York *Sun*. These chambers inclose a bent tube, through which cold air passes, supplied by any blowing apparatus, and in its course becomes heated; the hot blast thus produced will find an exit through the tuyeres into the furnace. When air of great heat is required, it is proposed, in place of the brickwork, to face the air-chambers with clay or stonework perforated with holes, through which the heat of the furnace passes direct to the chambers. Instead, too, of the heat of the air passing off from the chambers, it may be carried away from the furnace by pipes for other uses.

NEW FORMULÆ FOR CALCULATING TEMPERATURE.

In a letter to *Engineering*, P. H. T. J. Estler says, "Most formulæ connecting pressure and temperature in steam being somewhat tedious to manipulate, has caused me to place in your hands a formula, which so far as I know has never been published, and may be of value to engineers on account of its simplicity, and the satisfactory results which it gives between pressure of 10 pounds and 300 pounds absolute, limits most frequently employed.

Below I give the formula and some comparative results:

$$\text{Formula } \frac{p^{0.222}}{t} = .008484,$$

which may be reduced to the working form:

$$\log t = 0.222 \log p + 2.07140,$$

where

t = temp. in degrees Fahr.,

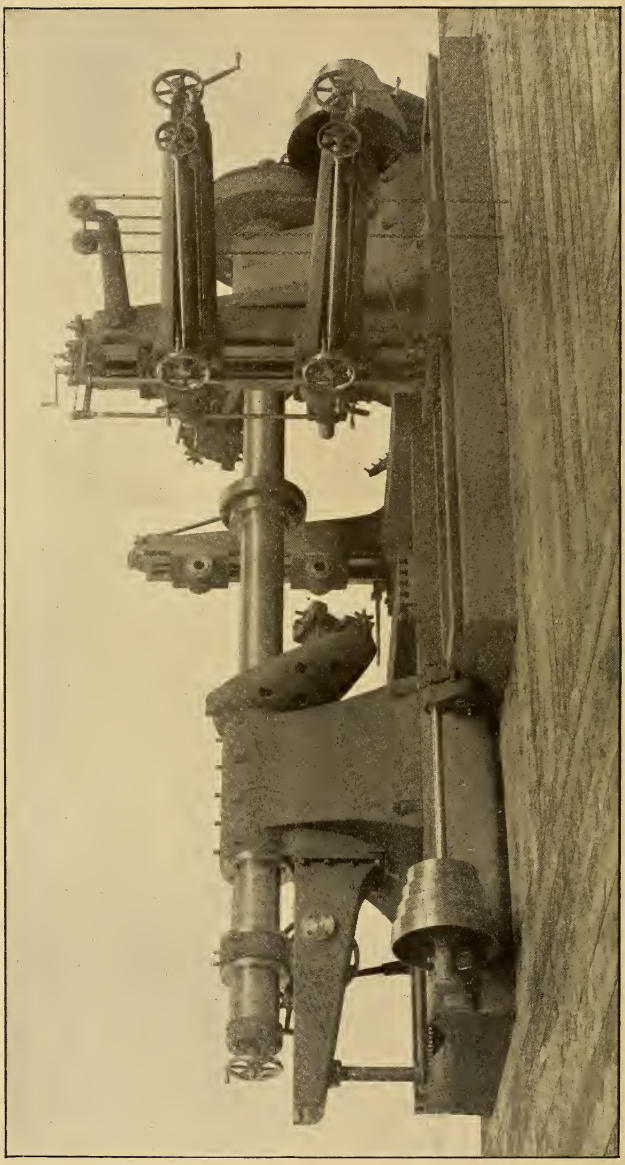
and

p = absolute pressure in pounds per square inch.

Below 20 pounds absolute the index 0.22 gives better results than 0.222.

Pressure in Pounds per Square Inch Absolute.	Temperature in Degrees Fahr. from Formula above.	Temperature obtained from Steam Tables.
5	167.9*	162.3
10	195.6*	193.3
15	213.9*	213.1
20	227.8*	228.0
25	240.8	240.5
50	280.9	281.0
100	327.6	327.9
150	358.5	358.3
200	382.1	381.7
250	401.6	401.1
300	418.1	417.1

*The index 0.22 was here used.



CORLISS CYLINDER BORING MACHINE. BUILT BY NILES TOOL WORKS, HAMILTON, O.
See page 58.

ELECTRIC LOCOMOTIVE FOR MILL USE.

THE *American Manufacturer*, in a recent issue, makes a good suggestion about electricity. It says:

"The present tendency to the general use of electricity as a motive power has much to commend it, but there is one line of work to which as yet, at least to our knowledge, it has not been applied, though we believe it might be so with profit to all concerned. We refer to its adaptation to light locomotives suitable for rolling-mills, steel works, and heavy machine shops.

"The ordinary steam locomotive for use about yards in the open air, used regularly up to something like its full capacity, answers its purpose well enough, and perhaps in the matter of economy it could not be excelled by any other form of motor, but in enclosed spaces, such as mills and other large manufacturing plants where locomotives must be used, some improvement is needed, and here we believe an electric locomotive of proper design would find a wide application. Its principal point of superiority would lie in its freedom from smoke, and also in that it consumes no power except at the moment of use. The smoke from the steam locomotive can perhaps be avoided by the use of coke as fuel, but this at the expense of filling the air with fine dust, which, in machine shops at least, is neither conducive to good work nor to the comfort of workmen. And in any case steam must be constantly kept up at the expense of fuel. The great problem, were electric locomotives to be introduced for this use, would be the transmission of the current to the motor. It is obvious that the overhead wire system would not answer under the conditions obtaining in most works, and it would appear that on account of the advantage of making the locomotive independent of external conditions, especially of the track, that the secondary battery is the most feasible. Most works of any magnitude have their own electric-light plant, which could be used during the day for the purpose of charging the batteries, two alternating with each other for each locomotive, without crippling the efficiency of either equipment.

"That electric power can be used safely and economically is now well settled. One firm, to our knowledge one of the largest manufacturers of overhead traveling cranes in this country, recommends the use of this power in preference to any other in machinery of that class, and it does not appear that the difficulties in the way of adapting it to locomotives for mill use are any greater than that for overhead traveling cranes. And with the freedom from smoke and dirt which an electric locomotive would give, other things being equal, it would possess a decided advantage over the steam motor. We should be pleased to see the problem taken up by some of the electric companies, for we believe its successful solution would inure to their benefit, and to that of large manufacturers and to their employés."

"THE question of supplying mines, mills, and other machinery in Red Mountain, Poughkeepsie Gulch, and tributary camps with electric power has been agitating the minds of capitalists and others in this section for the past season," says a Colorado paper, "but not until last month were active steps taken. The first power site secured was by ex-Senator Wallace, of Pennsylvania, and his associates. He was followed by Judge Sherman and others, who have the land and power at the confluence of Red Mountain Creek and Uncompahgre River, as well as the falls near River Side. The minimum power secured is 5000 horse power, ample enough for all the demands of the south end of the county, and being but three miles from Ouray, may prove a dangerous rival for the electric folks in this village. Electricity is the power of the future, and when nature provides the water power the expense is nominal."

Reflections and Observations.

During the past few years, at irregular intervals, someone has come along and given us such interesting information as "Edison is only an adapter. Has no originality." "Ericsson stole the idea of the *Monitor*." "Morse didn't invent the telegraph. No, no! I did." And now Corliss,—what cause he would have for pouring out his wrath if he were but alive! But that's the secret. We never would have learned that he didn't invent the valve which has given us the most economic engine ever produced. If he were alive, we would never hear anything about it. Were he here to speak for himself, we would not read that "Nat." Herreschoff created the greater part of Corliss's masterpiece, the famous Centennial engine, as he recently claimed in an interview in the New York *Herald*. According to the story, after he (Mr. Herreschoff) completed it, he "took" it to Philadelphia and set it up. One would think that it was put on a wheelbarrow or a handcart. It is a pity these great inventors always wait until someone dies before they file their claims. We may expect at any time to hear that Corliss himself was a myth,—didn't exist at all. All that is needed is time.

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When is an M.E. not an M.E.? I was asked recently for my opinion, and confess I could not give a satisfactory answer. It is well enough to say an M.E. is an M.E. when he *is* an M.E., as a physician is an M.D. or a minister a D.D.; but when we find a man with an M.D. tacked on his name, unless the degree has been granted to him in an established institution having the authority, we protest against it and look with distrust upon him. Various colleges grant different titles. Some give a B.S. upon graduation and an M.E. *after* the graduate begins actual practice and accomplishes something. Others grant the M.E. when the student completes the course, and give a still higher degree of M.M.E. in special instances, while others have still different titles. The question is, Should a man who has not had the college degree granted him make use of the title M.E.?

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To my mind custom decides the matter for us. A man who is a practical mechanical engineer, in advertising the fact states simply that is his business. He makes no claim to be a college graduate, and I doubt very much if the man who employs him ever thinks anything about the title except as a designation of his business. Without questioning for an instant the great benefits resulting from the newer form of technical education as is pursued in such colleges as Cornell, Stevens Institute, Boston Institute of Technology, Worcester Polytechnic School, and many other institutions, it would be folly to assert that the many men who are to-day producing our greatest improvements in steam machinery are not mechanical engineers because they have no parchments to put in a frame. They have served their time and had the practical experience which such work gives them. They make mistakes. Their experiments may not always be successful, but the college graduate would probably do no better after as many years of actual practice. You can count on your fingers the men who to-day are improving our steam engines. With hardly an exception, they are not college graduates. When they were young men the improved technical school did not exist. The next decade is likely to show what the college man can do, and we have no doubt he will acquit himself creditably. But meanwhile the mechanical engineer,—what else can he call himself?—who had

the misfortune to be born too soon, is doing noble work.

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THE colleges would do a wise thing if they adopted a uniform system of degrees. Whatever title be decided upon for completion of certain studies, should be the same, whether the education be received in Boston or New York. If it is M.E., it would seem to be wise if a higher degree were to be granted at a later day. If it should be B.S., and was followed at a proper time by the higher title of M.E., the same object would be accomplished. A careful consideration of the question by the eminent teachers at the various schools of engineering may bring out a plan that will be both beneficial to the student and the college.

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IN their effort to obtain laws governing the examination of engineers who are to be in charge of steam plants under pressure, the engineers' associations should receive all the aid and influence that it is possible to give them. They do not ask that all engineers should belong to this or that association, but think there should be an efficient regulation which will prevent an incompetent man from being in a position where he can endanger the lives and property around him. Such a law should not be local, but national. It should be uniform in each State, and if the builders of engines, boilers, and other parts of a steam plant, who have much to lose by the incompetent management of the goods they sell, gave the matter the attention it deserves, they could be of incalculable help to the associations, which are doing the whole work unassisted.

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SOME time ago I called upon the Keely Motor Company in Philadelphia to learn how soon they would put the "commercial" engine upon the market. According to the secretary's (they have a secretary) statement to me every detail is now perfected, and had it not been for an accident to a special part which was made to order in Paris, the engine would have been ready some time ago. Owing to this unfortunate occurrence another delay is inevitable, as they were compelled to send abroad for a duplicate, which, however, shortly will arrive. Soon after that important event takes place we can tear down our workshops and melt our locomotives. The engineer can buy a "fiddle," the fireman a harp, and should these instruments be unobtainable we need only sing a chorus, striking the right "mass-chord," to obtain sufficient power to move the world.

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HAVE you ever thought that Keely was not the great fraud we all think him to be? Not that I have been converted into believing his claims, but I have thought he imagines, or at some time did believe, he had actually discovered a force which was new. Acting on this idea, he may have at first been honest in his experiments. He found it possible to obtain money for them, and when he at last did see his idea was impossible he determined to continue his "experiments" as long as the stockholders would continue to supply the money for the same. It is a peculiar fact that his greatest supporters and admirers have been women, who even to-day have confidence in his ultimate success.

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SEVERAL times a year some one comes along with an "exposure" of Keely's secret and claims the ability to perform the same feats in the same way, but while there is little doubt that Keely's motor has a trick about it, no one has yet actually discovered his compressed-air plant or his electric-power connection, or any method used in producing the results. The investigators have made assertions, but so far as I know, Keely's scheme is yet unknown. He has been able to mystify the many eminent engineers who have at various times been present at his experiments, and while they doubted his ability to perform the feats in a legitimate manner, they have not learned the secret.

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KEELY claims the engineers of the world have never treated him honestly or fairly; that the press has abused and maligned him. He compares himself to the persecuted inventors of a century ago, but he does not state that while

they starved for want of encouragement he has lived on the fat of the land. Mr. Keely has enjoyed life for twenty-two years fairly well under these terrible persecutions, and while he is aging he has probably many years to live. Still, as the secretary of the company informed me, it was the heartfelt wish of every one of his friends that he would be spared to the world long enough to perfect his motor. In which we all concur.

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MEANWHILE we will have to content ourselves with Edison's latest motor, which will enable us to travel 100 miles per hour. Of course that is slow compared to the results we will obtain with Keely's, but Edison is more fortunate in not requiring any castings made in Paris, or wire from Bombay. While we can get all our materials for a motor here, even if it does require a little more iron and copper and wire, as well as brains, we will do the best to put up with such crude affairs a little longer; but please, Mr. Keely, take pity on us and don't keep us waiting twenty-two years more.

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THE "oil that lubricates most" is the way a well-known oil firm goes at the question, and it seems to me that the oil which actually does lubricate the most would be the oil that everyone should be using. There are so many poor engineers in charge of steam plants, however, that the man who pays the coal bill too often decides upon the size of the oil bill, with the result of a saving in oil at the cost of coal. He may not know it, but there is a greater difference in the question than the price per gallon, and very often if he did he would find the oil he buys would be dear if it was sent to him gratis.

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SUCH an eminent authority as Professor Thurston has stated that a saving in power of 50 per cent. has been shown by a change of oils; and while this is perhaps an extreme case, there is no question of the immense waste in power caused by poor oil. The man who pays the oil bill will learn in time that the cheap oil is adding 5 or 10 or 20 or even 50 tons of coal to his bill out of every 100 used. Then he will look around for a good engineer, whose opinion and experience with oil will show him the difference between the reduction in the oil bill and the increase in the ash pile.

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MANY manufacturers who are moving their plants to out-of-the-way, unheard-of places, because an offer of free or cheap land is made them, would be wise if they looked up the inducements offered by cities near the market where their goods are sold. There are dozens of places on the line of the Erie Railroad, near the center of iron and coal industries, as well as among the natural gas and oil districts, or near enough for all practical purposes, where they can make as good arrangements for locating as they could in these mushroom towns. Besides, they have the additional advantage of proximity to the labor supply. The Erie Railroad makes especially advantageous arrangements with manufacturers.

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HOHOKUS is one of the many places near New York, on the line of this road, which offer exceptional inducements for new enterprises, several of which are now locating there. Among the new industries are to be a cotton mill and a woolen mill. The Hohokus River, which runs through the place, has a heavy fall, which can be easily utilized for supplying both power and light, all that can be obtained in many towns in the West whose attractions are free oil or natural gas. This town is only one of hundreds on this and other roads, and if the same attention was given to booming such near-by places, we would hear of their growth to cities even larger than those that are started in the wilderness.

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BUT the towns near New York are not the only ones which offer excellent opportunities for new manufacturing enterprises. Around Philadelphia, Buffalo, and Chicago, as well as hundreds of well-known cities, there are localities which would give much for new industries. A little of the push and go which distinguish the Southern and Western land agent is all that is needed. X.



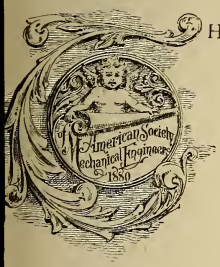
Chas. H. Loring

President American Society of Mechanical Engineers.

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AMERICAN SOCIETY OF MECHANICAL ENGINEERS.



THE material monuments of the day do not always perpetuate the fame and worth of their builders. The structures survive through ages, and continue to inspire wonder and admiration long after the genii that reared them have passed away forgotten. The work stands, but the identity of the master hand which created it is no longer remembered. Examples of this are not wanting, and unfortunately are but too numerous. How many are there outside of the engineering profession who can recall to mind without reference to books the name of the engineer through whose skill has been reared the great and famous structure over the Firth of Forth, in Scotland? Still fewer, perhaps, are there who are familiar with the genius whose fame one might say lies hidden in the cavernous recesses of the Thames Tunnel! But one need not go abroad to learn how fleeting and shadowy sometimes is this bubble reputation, for we can readily learn the lesson at home. The Brooklyn Bridge is a magnificent achievement and a fitting monument to the endowed spirit which planned it, and yet, though he has only recently gone from among us, but few there are who can readily recall him to memory. The St. Louis Bridge is another silent monument; to the world the builder to-day is virtually forgotten —unknown. Who remembers the name of the architect of the great *World* building in New York, or the tallest monument in the world, the Washington? What is the name of the engineer who planned the great New York Aqueduct?

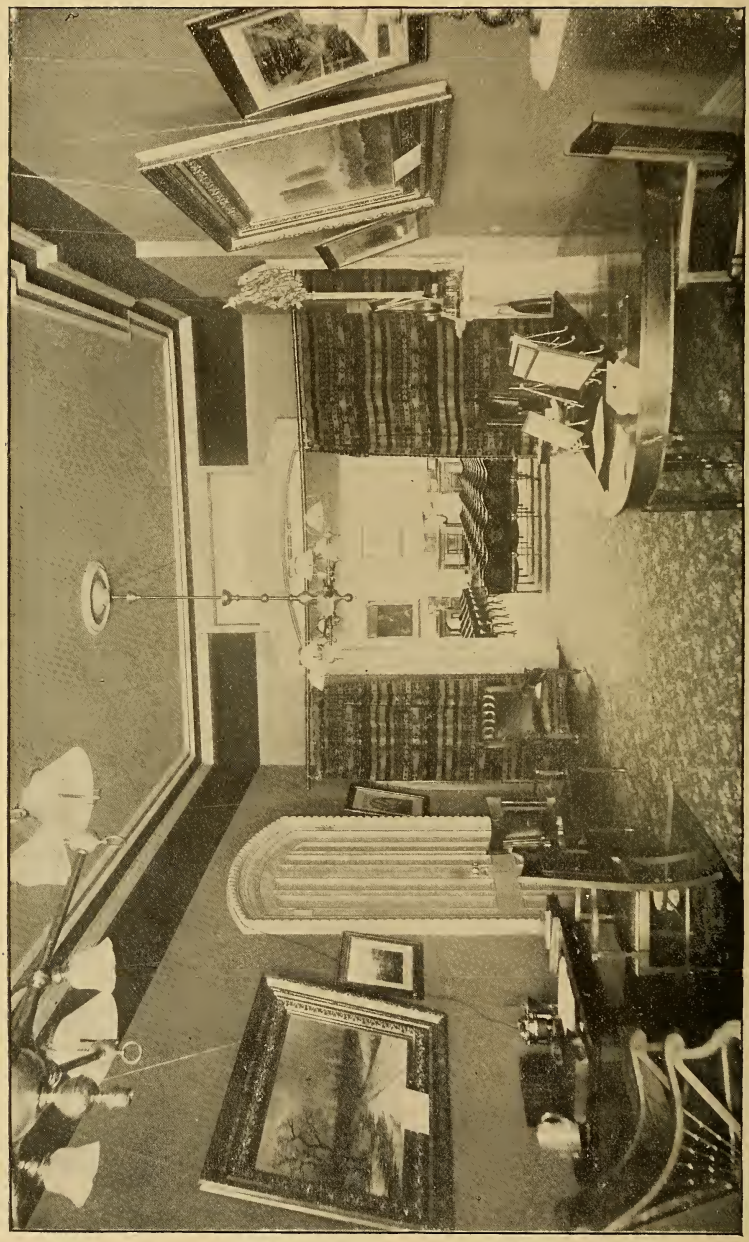
One readily discerns in all this that fame rests not wholly upon massive structures. Genius is remembered rather for its ultimate influence upon the human mind and upon human progress than for its immediate material results. It is upon this enduring basis that the fame of the inventions and work of Watt, of Ericsson, of Morse and of Faraday, of Edison and of Corliss, of Bessemer and of Holley, is reared, as a beacon to lead others on to enlightenment and wisdom, and to further effort for the good of mankind; and so the mechanical engineer will be remembered long after the immense bridges, the long aqueducts, and the grand architectural structures have crumbled into dust and the master hand which designed them has been forgotten.

Thus, in measuring individual merit from this standpoint, the world cannot but admire and remember the many ambitious toilers who are burning the midnight oil in exacting research and analysis in behalf of a theory or principle whose benefits are limited neither to time, place, nor race, but are universal in every sense.

These reflections suggest themselves *apropos* of the achievements of many members of the American Society of Mechanical Engineers.

The career of the newly-elected president of the Society, Charles H. Loring, whose portrait is shown on the preceding page, has been a very interesting

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AMERICAN SOCIETY OF MECHANICAL ENGINEERS.—RECEPTION ROOM.

one. Mr. Loring is of New England lineage, being of the seventh generation on either side. He received his preliminary education in the public schools, afterward serving a four years' apprenticeship in a mechanical establishment in Boston. It was here that he gathered his early taste for engineering. He entered the United States Navy in 1851, and passed through the successive grades of the engineer corps, finally reaching the rank of chief engineer in 1861,—just in time to be of service in the war. He was engineer of the fleet in the North Atlantic blockading squadron during the first eighteen months of the Rebellion, participating in the famous battle between the *Monitor* and the *Merrimac* in Hampton Roads. He was afterward general inspector of all the ironclad vessels under construction west of the Alleghenies throughout the remainder of the war period, building in that time on the Ohio and Missouri rivers eleven turreted vessels which rendered substantial service in the cause of the Union. History accords Commander Loring enduring credit for the gigantic work which he accomplished for the navy of the United States during the momentous four years beginning with 1861. No less important in a scientific way have been his subsequent achievements.

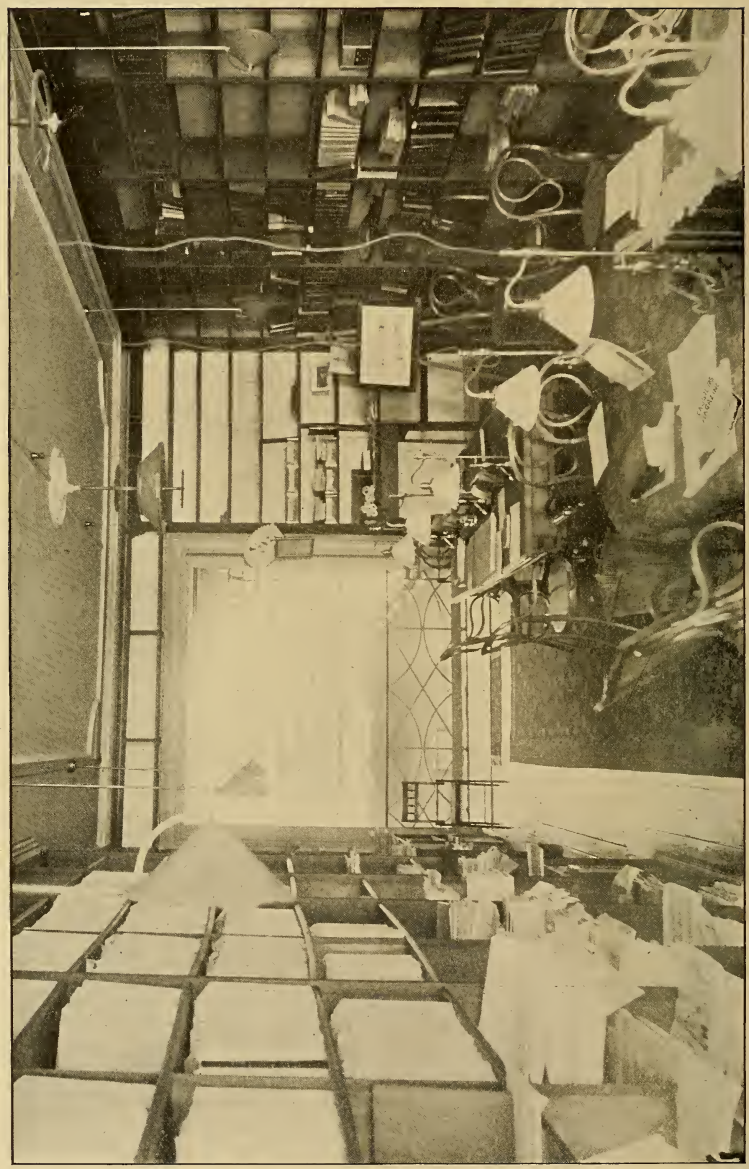
In 1872, associated with Chief Engineer C. H. Baker, U.S.N., he investigated and reported upon "the theory and practice of the compound engine" to the Navy Department, and in harmony with the recommendation contained in the report the first compound engines used in the navy were designed and built under their supervision. Two years later, in 1874, Mr. Loring conducted with Dr. Charles E. Emery the once famous competitive trials of the simple and compound types of engines with the machinery of the revenue-cutters *Rush*, *Dexter*, *Dallas*, and *Gallatin*.

President Arthur recognized his work and worth by appointing him, in 1884, chief of the Bureau of Steam Engineering, in which capacity he rendered substantial service. Though retired—under the law—from the activities of the naval service, President Loring is still vigorous and active, being superintending engineer of one of the largest and most important steamship lines running out of New York harbor.

The American Society of Mechanical Engineers was organized nearly twelve years ago, the preliminary meeting being held in New York city, February 16, 1880, upon a call signed by Professor R. H. Thurston, Professor John E. Sweet, and the late Alexander L. Holley. There were about forty gentlemen in attendance, and A. L. Holley was chosen chairman of the meeting, and S. S. Weber, secretary. The full organization of the society was completed at a meeting called for April 7, 1880, in the lecture-room of Stevens Institute of Technology, at Hoboken, N. J., at which meeting the first draft of rules for the society was adopted, and the initial steps completed, and at the conclusion of this meeting Professor Henry Morton entertained the society at his residence. The first public meeting for the reading of papers and their discussion was called for the 4th of November of that year, and since that time regular meetings in the spring and fall have been held in the different cities; up to the present time only as far west as Chicago, but the next meeting will necessitate a journey across the continent, as San Francisco has been selected as the city for the spring meeting.

The society's first offices were those of its first secretary until 1883. At that time, when its membership had increased from 189 in September of the first year to 364, it rented a business office for its growing needs at 15 Cortlandt street, where it remained until 1885, when it moved into a larger space, made necessary by its rapid growth, at 280 Broadway. There it remained, finding its quarters growing more and more inadequate, until 1889, when it was decided to abandon the business center of the city and move up-town to the resident district, in order that its office and library might be open in the evening,—a practice inconvenient in the business section.

In 1889 the society moved to 64 Madison avenue, where the abundant success of the evening meetings and the enthusiastic interest in the society and its welfare made even that greatly increased accommodation still too narrow for what was considered the best interests of the



AMERICAN SOCIETY OF MECHANICAL ENGINEERS.—READING ROOM.



F. R. Hutton

Secretary American Society of Mechanical Engineers.

society. Accordingly, in the winter of 1890, the fact that the house at 12 West Thirty-first street, occupied by an organization of physicians, was for sale was brought to the notice of the council. Considerable money had been spent by this medical society altering the house for their needs, which were so nearly parallel to those of the Mechanical Engineers that very little or no alteration has been called for to adapt the building for the society's needs. The illustrations we print give very good views of several of the rooms. The society was at that time but ten years old; it was felt that there was a certain boldness in proposing that it should become the owner of its own house, and before the steps looking to securing the property could be undertaken, a guarantee fund was created, so that there should be no uncertainty in the move toward acquiring possession of the property. The members of the society were approached to know whether they would support this move by furnishing the necessary amount of money to effect the purchase, the money to be loaned, the loan to be secured by mortgage, and the interest upon the loan to be paid as coupons of bonds purchased by the subscribing members. No difficulty was encountered in obtaining the necessary subscribers, and the house was purchased for the market value of $60,000. The correspondent of *Engineering*, in writing of this, said it was a brilliant financial operation which should be classed among the achievements of Wall street. The society bought $60,000 worth of property and yet laid out none of its funds in so doing. Its success is largely due to the personal activity and shrewdness of Professor F. R. Hutton, its secretary, and as a financial and model secretary it is believed he is without a peer in this country.

Although Professor Hutton is perhaps best known to the engineering profession through his long services as secretary of the Society, his career covers a wide range of brilliant and substantial work. Born in New York city in 1853, he received his education at Columbia College, taking the classical course in 1873, and graduated from the School of Mines three years later. Appointed instructor in mechanical engineering in the Columbia School of Mines in 1877, he was promoted in 1882 to the office of adjunct professor, and finally this year reached the full professorship. From 1880 for two years he was engaged as expert for the tenth census, writing the monographs and reports on pumps and pumping machinery, machine tools, and wood-working machinery. He was elected secretary of the American Society of Mechanical Engineers in 1883, and his services in that position have been so efficient and useful that his re-election has regularly followed at every meeting since that time. Though devoting attention to this work, he also retains his position of Professor of Mechanical Engineering at Columbia College, and so high does he stand in his profession that he is frequently called upon to give expert testimony before the courts. As constructing engineer he also finds ample demand for his services in designing and erecting steam plants for heating and power purposes. His unlimited capaccity for hard work, coupled with excellent judgment, ripe methods, and a wide range of knowledge, furnishes him with a most valuable equipment for the exacting demands of his continued labors.

Wm. H. Wiley, who has occupied the responsible position of treasurer of the society since 1884, is one of its most active members. After four years of study at the college of the City of New York, Mr. Wiley entered the United States Army at the outbreak of the war as first lieutenant, and through meritorious services rose to the rank of captain and was breveted major. In September, 1864, he was graduated a civil engineer from the Rensselaer Polytechnic Institute, at Troy, and at once started upon an active professional career. He successively did good service at the Brooklyn Water-Works and the Croton Aqueduct, and with the Philadelphia and Reading Railroad Company. Later on he took a course of mining at Columbia College, and on completing it became superintendent of a Western mine, remaining there for several years. He joined the American Society of Civil Engineers in 1867, and was one of



AMERICAN SOCIETY OF MECHANICAL ENGINEERS—LECTURE HALL.





Treasurer American Society of Mechanical Engineers.

the founders of the American Society of Mechanical Engineers. He is also a member of the Institute of Mining Engineers, of the Institute of Electrical Engineers, the Loyal Legion, and Engineers' Club, and has been treasurer of the American Society of Mechanical Engineers continuously since 1884. He has been for three years a member of the Township Commission of East Orange, being chairman for one year, and also chairman of the Fire Committee and of the Sewerage and Drainage Committee. For seven years he has been the New York correspondent and representative of the well-known English technical journal, *Engineering*. Mr. Wiley is a member of the well-known firm of John Wiley & Sons, publishers of scientific text-books and industrial works, New York city. It will thus be seen that Mr. Wiley's labors cover a wide range of activity and usefulness in which the public comes in for a large portion of the benefit. The portrait of Mr. Wiley printed on the preceding page is a very good likeness.

The membership of the society when the building was purchased numbered about 1000, the increase in each year from 1883 being from 60 to 120, until last year, the year of the transition, when the phenomenal increase of 205 to the membership was a substantial confirmation of the wisdom of the bold policy, the membership at the present time being about 1400.

There is no question but what the trip made by the society and ladies, led by its officers, to visit England and France, in 1889, has had a very important bearing upon its present prosperity. The number of the members with their ladies who formed the excursion was 190 of the entire 360 in the party, and at one of the social reunions which was held in the house of the society this autumn an exceedingly enjoyable feature was the reproduction upon lantern slides of several photographs taken by the members of the party during that most delightful trip.

These social reunions referred to have been a feature of the society's house-life. They are in no sense meetings of the society, inasmuch as their expenses are borne entirely by the members participating, who bring with them their wives and other ladies, thus adding very much to the social enjoyment of the occasions. The reunion groups itself about some central feature, the programmes for the winter involving reminiscences of Robert Fulton, reminiscences of early railroading, the history of electricity prior to Galvani, and evenings of tribute to the memory of eminent engineers whom the society delights to honor.

The society moved into its new premises on May 8, 1890. The main floor consists of a saloon parlor used as a reception room and office, as shown in our illustration; at the back of this is the auditorium, with comfortable folding seats for 160 persons, the room being large enough to extend its capacity to 200 by movable seats at the back.

On the basement level is a front room used as a council chamber and typewriter's office, while underneath the auditorium, in the rear, is a large room 20 feet by 40 feet, in which tables can be spread for collations and other social functions which are discharged in the house.

The library of the society is accommodated upon the second floor, the entire level being covered with shelves, and having a space of 98 feet in depth, and varying in width from 20 feet to 28 feet for the accommodation of books. The shelving capacity has a limit only a little short of 20,000 volumes. As yet this limit is by no means approached, there being room left for growth considerably beyond the modest nucleus with which the young society has begun. Secretary Hutton's private office is also upon the second floor.

The third and fourth floors have been fitted up as sleeping apartments for the use of the non-resident members of the society. There are six of these rooms plainly but comfortably furnished, the mattresses being specially luxurious, and abundant use has already been made of these notable conveniences by the membership distributed over the large area covered by the society.

In one of the rooms on the third floor is located the business office and council room of the American Institute of Elec-

trical Engineers, who have, with the Mechanical Engineers, the privilege of putting their books upon the library shelves, and who are in respect to their relations with the Mechanical Engineers their tenants. The fourth floor contains the janitor's quarters and a bath-room, in addition to the toilet facilities furnished on the third floor and basement. The water for the top-floor rooms is supplied from a tank, into which the water is pumped by an electric motor operating a three-throw pump, the switch controlling the motor being automatically operated by a float in the tank, so that the latter is always kept full. The walls of the auditorium are two stories high, and are decorated with the pictures of the genial and lovable Alexander L. Holley, deceased, founder of the society, and one of its first officers, and with that of Sir Henry Bessemer, honorary member of the society, presented by himself. Also with that of Professor Rankine, which hangs over the chairman's desk. In the alcove of honor overhead hangs a reproduction of the Scott portrait of James Watt in the position of patron saint of the profession.

The front drawing-room and halls are enriched by paintings and photographs, gifts to the society from interested members, and over the center of the auditorium is the society's seal, representing the lever of Archimedes moving the world. This is in stained glass laid in a tinted panel, by which the overhead light is softened as it falls into the room below. The house is illuminated throughout with Edison incandescent lamps, the library, in particular, as shown in our illustration, being so lighted that each worker commands a table standard for his exclusive use, while the illumination of the room is derived from reflection from the book-shelves, which are illuminated from lamps that are shielded from the room by opaque shades. Readers have said that the manner of lighting in this way makes the most charming and satisfactory illumination by which to work.

The library of the society is maintained as a free public library, and is open to all readers from ten o'clock in the morning until ten in the evening. The glow-lamp method of illuminating renders it possible to have the library open by night without the injury that is done to books by burning gas.

The auditorium is fitted with a most admirable screen for projection purposes, and the lantern which is used is so arranged that an arc electric light switched into the circuit which illumines the house furnishes a steady and brilliant white light, much superior in quality to that given with the oxyhydrogen lime-light, and with much less annoyance to the operator. The focussing lamp is a gift to the society from the Clark Electric Company, of this city, the mounting and adaptation of the lenses, etc., having been done by the indefatigable secretary of the society, to whose active and interested efforts so much is due of the planning and preparation of the house. A glance at the past officers of the society shows names well known all over the world as among the prominent engineers of the day:

R. H. Thurston, president, April 7, 1880–November 3, 1882.

E. D. Leavitt, Jr., president, November 3, 1882–November 3, 1883.

John E. Sweet, president, November 3, 1883–November 7, 1884.

J. F. Holloway, president, November 7, 1884–November 13, 1885.

Coleman Sellers, president, November 13, 1885–December 2, 1886.

George H. Babcock, president, December 2, 1886–December 1, 1887.

Horace See, president, December 1, 1887–October 18, 1888.

Henry R. Towne, president, October 18, 1888–November 22, 1889.

Oberlin Smith, president, November 22, 1889–November 14, 1890.

Robert W. Hunt, president, November 14, 1890–November 17, 1891.

Lycurgus B. Moore, treasurer, April 7, 1880–December 2, 1881.

Lycurgus B. Moore, acting secretary, April 7, 1880–November 4, 1880.

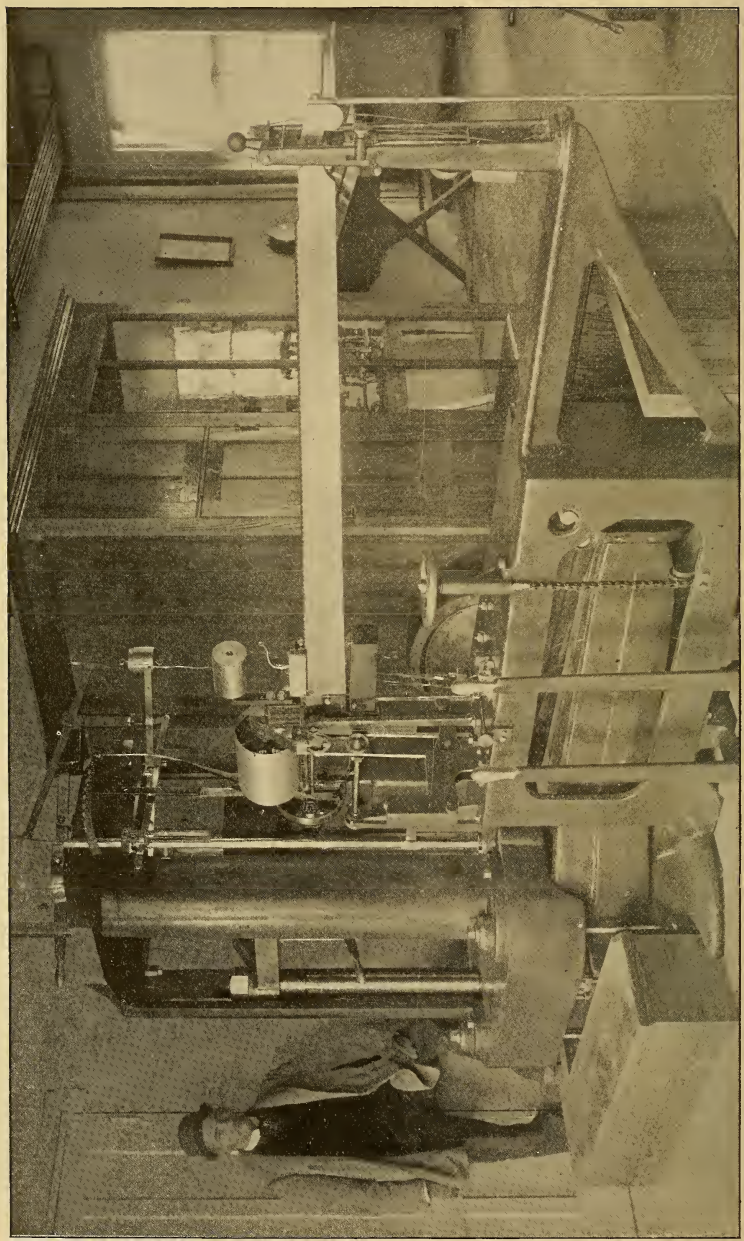
Thomas Whiteside Rae, secretary, November 4, 1880–March 1, 1883.

Charles W. Copeland, treasurer, December 2, 1881–November 7, 1884.

The present officers are: president, Charles H. Loring; F. R. Hutton, secretary, 1883 to present time; W. H. Wiley, treasurer, 1884 to present time.



PART OF 7000 HORSE-POWER PLANT OF BABCOCK & WILCOX BOILERS AT THE WORKS OF THE SOLVAY PROCESS COMPANY, SYRACUSE, N. Y.

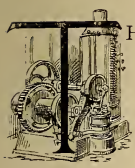


300,000 POUND TESTING MACHINE.—SIBLEY COLLEGE, CORNELL UNIVERSITY.

TECHNICAL SCHOOLS OF AMERICA.

NO. I.—THE SIBLEY COLLEGE LABORATORIES, CORNELL UNIVERSITY.

By Professor R. C. Carpenter.



THERE have been workshops well equipped with tools in which students received instruction in wood-working, blacksmithing, moulding and foundry-work, and in the machinists' trade since the first organization of Sibley College, Cornell University, in the year 1868.

These shops are laboratories, in which the student receives practical instruction in the use of tools and in the fundamental arts which form the basis of his after-work in mechanical or electrical engineering.

It is not, however, the purpose of this article to describe these shops or the methods employed in instructing the students in these practical and useful arts, save to mention that during the entire course of four years nine hours per week are devoted by each student in these shops in acquiring practical skill in the various handicrafts taught.

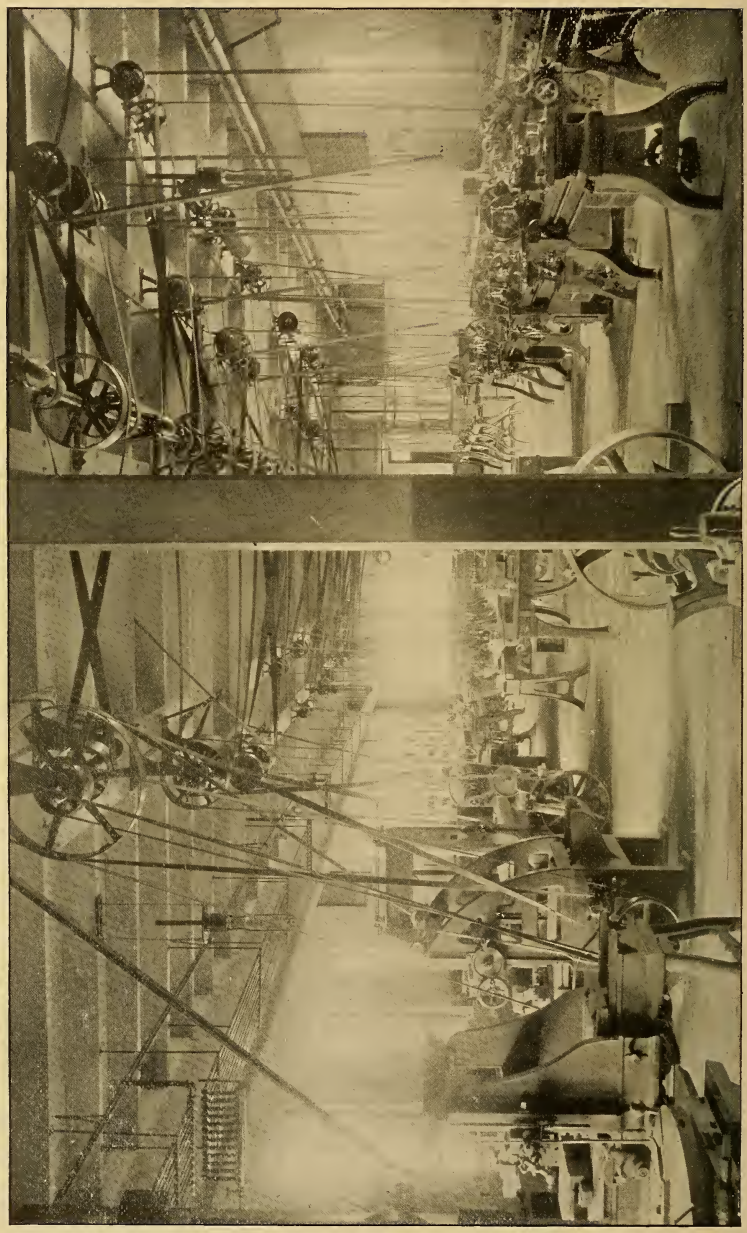
The skill acquired, except in rare instances, or unless the student has had practical training previous to his entering the college course, is not sufficient to make journeymen in the various trades; indeed, that can hardly be said to be any one of the objects of the course in shop-work. It is rather to give engineers that practical knowledge of tools and of materials needed to design and execute works later in life. It is true, however, that while students cannot compete with journeymen mechanics in the amount of work produced, very much of this work is of high quality, and would be a credit to any skilled workman. The course laid out is one that every student must take, or else satisfy his instructor that he has had the necessary training elsewhere. It consists largely of the construction of special models, designed with the end in view of giving to those who complete them skill in the use of tools and knowledge of the details of various machines. The course is supplemented later, after the student has acquired the necessary practical knowledge, by a course in which he will obtain experience in the construction of complete machines or engines. Many manual training schools have done more in the way of actual construction than the shops at Sibley; yet even in the Sibley shops the aggregate of such work is considerable. A visit to the machine shop at the present time would show a duplex pump nearing completion, and finished in a manner creditable to any shop in the country. Other constructions are in progress, and various machine tools, built by the students, are in daily use. In the experimental engine room is to be seen to-day in good condition the pioneer of the "straight-line engine," built at the shops when Professor John E. Sweet was its superintendent.

More ambitious constructions are anticipated in the future, and the design of a triple-expansion engine of about 70 H.P. is nearly completed, and will be built in time for the Chicago Exposition.

The work done in the foundry and the blacksmith shop has always been of a practical nature, and many examples of the skill acquired elicit praise from trained mechanics.

In addition to the workshops are the laboratories for investigation and scientific research. These laboratories relate to electrical and to mechanical engineering, the two principal courses of Sibley College. The laboratory of electrical engineering is well equipped with dynamos and electric motors of all the principal manufacturers of this country, donated for this purpose to Dr. Thurston in order to provide for the practical education of electrical engineers.

The investigations that have been



THE MACHINE SHOP.—SIBLEY COLLEGE, CORNELL UNIVERSITY.

made in this laboratory in the past under the direction of Professor W. A. Anthony, and in more recent times by Professors Nichols, Ryan, and Mohler, have made the laboratory famous and well known to every electrician in the country.

The course of instruction is in charge of the Department of Physics, and requires, first, a sufficient amount of practice to render the student familiar with electrical measurements and electrical apparatus; second, the actual work with this apparatus, and the making of efficiency tests of the various electrical machines; and third, research and investigation of matters of importance to electrical engineers.

All students in the course of electrical engineering devote eight to twelve hours per week during the last two years of the college course to this work.

The laboratory of mechanical engineering was started by Dr. Thurston in 1885, on first assuming the duties of director of Sibley College. Through his active exertions improvements to the plant have been made from time to time, and in 1890 the laboratory was organized as one of the departments of the college. The time devoted by the students to laboratory work was very much increased, and a large sum of money was devoted to the improvement of the plant. In this laboratory are included special laboratories for the investigation of the following subjects:

(*a*) Strength of materials.
(*b*) Hydraulics and hydraulic motors.
(*c*) Friction and lubrification.
(*d*) Transmission of power, dynamometers.
(*e*) Steam engines, hot-air and gas engines.
(*f*) Air-compressing machinery, rock-drills.
(*g*) Heating and ventilating machinery.
(*h*) Elevators and mining machinery.

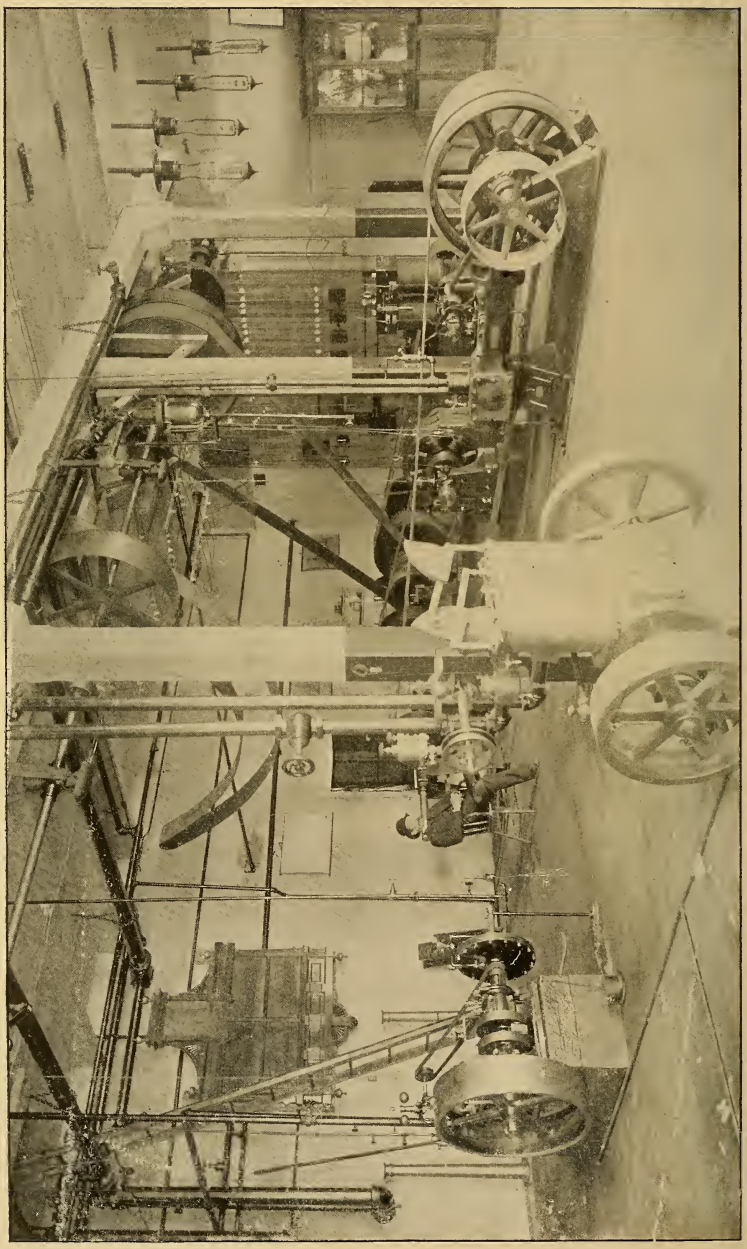
While these laboratories are largely devoted to investigation and research, they are also of great value educationally, as they afford the best possible opportunity of illustrating and applying the principles advanced in the classroom. They thus tend to fix in mind and show the application of what would otherwise be regarded by the student as abstract and without practical value. The laboratories also give valuable instruction regarding methods of testing, and serve to train skilled observers for accurate investigation later. Incidentally they afford students an opportunity, and about the only opportunity they can obtain, for practically handling and directing the operations of various machines or engines, and such knowledge is of great service in after-life. The investigations which can be carried on in such a laboratory may be as varied in character as the scope of the course or extent of the equipment will permit, and are not likely to be limited by any consideration of the course of instruction laid down in the catalogue.

This fact is well illustrated by consideration of a few of the subjects of investigation the past year in the laboratory of Sibley College. These were as follows:

Efficiency of steam separators, Brill and Meeker; test of the Auburn pumping engine, Almiral and Shapleigh; efficiency test of the Utica Electric Railway, Heilman and Clarke; aluminium and its alloys, J. E. Kress; efficiency of steam radiators, Jackson and Kelsey; efficiency test of the Rochester Electric R. R., Bedell and Hall; specific heat of steam at high pressures, Stewart; tests of aluminium, Graves and Hagget; power absorbed by metal-cutting tools, Bierbaum and Wood; tests showing expenditure of energy in an electric-lighting plant in New York city, Darlington and Cowen; efficiency tests of injectors, Burwell and Arnold; efficiency test of an engine, before and after treatment with a non-conducting material, D. Rouse; efficiency tests of several power and electric plants in the city of Ithaca, of steam pumps and water motors, and of several calorimeters were also made.

As showing the methods of instruction and the apparatus available for this purpose, the following descriptions are taken from the special instructions to students in the notes of the laboratory lectures:

This course differs from that in a physical laboratory in its subject-matter and in its application, but the methods



OLD LABORATORY FOR ENGINE TESTING.—SIBLEY COLLEGE, CORNELL UNIVERSITY.

of investigation are to a great extent similar. In the engineering laboratory one will be occupied principally in finding coefficients relating to strength of materials or efficiency of machines; these from the very nature of the investigation cannot have a constant value, which will be exactly repeated in each experiment, even provided no error be made. The object will then be to find average values of these coefficients, to obtain the variation in each specific test from these average values, and if possible to find the law and cause of such variation.

The results are in general a series of single observations on a variable quantity, and not a series of observations on a constant quantity, so that the method of finding the probable error, by the least squares, is scarcely ever applicable. This makes it nearly impossible to ascertain and correct for the personal error of the observer, for this reason it is essential that unusual care be taken that the observations be made correctly, and with accurate instruments.

It requires much skill and experience in order to deduce general laws from special investigations and there is always reason to doubt the validity of conclusions obtained from such investigations if any circumstances are contradictory, or if any cases remain unexamined.

On the other hand, theoretical deductions or laws must be rejected as erroneous if they indicate results which are contradictory to those obtained by experiments under the conditions supposed to exist in both cases.

The method of investigation or experiment is to be considered as consisting of three operations: first, to standardize or calibrate the apparatus or instruments used in the test; second, to make the test in such a way as to obtain the desired information; third, to write a report of the test, which is to include a full description of the methods of calibration, and of the results, which in many cases should be expressed graphically.

The methods of standardizing or calibrating will in general consist of a comparison with standard apparatus, under the conditions as nearly as possible the same as those in actual practice.

The report is written in a blank-book of a standard form as prescribed by the laboratory instructors and is accompanied with a duplicate log of the test to be filed in the laboratory.

The courses of instruction at present relate to the calibration of laboratory apparatus; tests of the strength of materials; tests of friction and lubrication; efficiency tests, which relate to belting and machinery of transmission, water-wheels, pumps, and hydraulic motors, hot-air and gas engines, air-compressors and compressed-air machinery, steam engines, boilers, injectors, and direct-acting pumps.

The following is the detailed course for each term:

Junior Year of Fall Term—Strength of Materials—Tension and transverse. *Calibration*—Transmission dynamometers; indicator springs and steam gages; weirs and meters. *Six lectures.*

Winter Term—Strength of Materials—Compression and torsion. *Oil Testing*—friction. *Steam Engine Preparatory*—Flue gas analysis; air thermometer; calibration of thermometers; calorimeters; indicator practice. *Six lectures.*

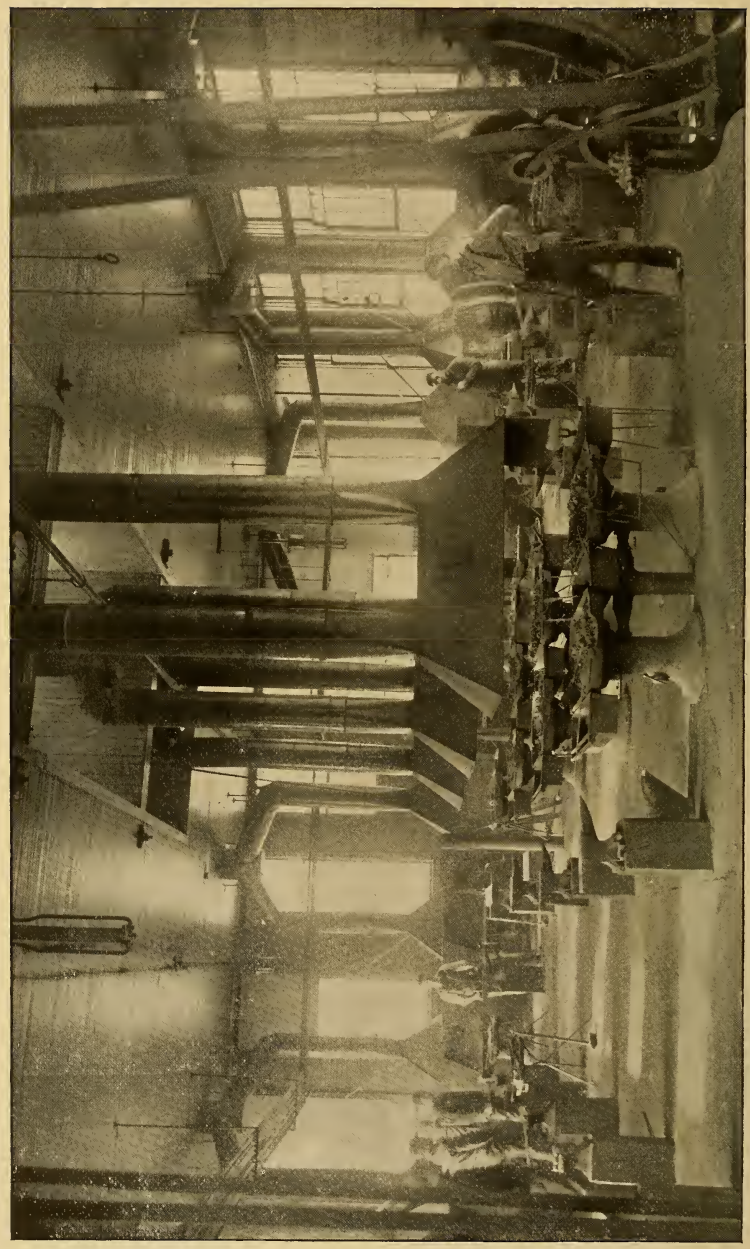
Spring Term—Strength of Materials—Impact; flexure. *Lubricants*—Viscosity; durability. *Valve setting*—Steam engine. *Efficiency tests*—Water motors; steam boiler; steam pump. *Six lectures.*

Senior Year—Fall Term—Strength of Materials—Brick; stone; cement. *Efficiency Tests*—Steam engine; hot-air engine; gas engine; injector; centrifugal pump; hydraulic ram; belting. *Six lectures.*

Winter Term—Steam engine, by Hirn's method. *Efficiency Tests*—Air-compression; electric-light plant; manufacturing plant; compound steam engine; triple-expansion steam engine. *Six lectures.*

Spring Term—Hirn's method tests of compound engine; triple-expansion engine. *Efficiency Tests*—Locomotive; turbine water-wheel; windmill. Special research. Thesis work.

The course outlined above is intended to educate the students regarding the methods of testing, and to give them practice in the use of apparatus and in handling machinery; following this



THE BLACKSMITH SHOP.—SIBLEY COLLEGE, CORNELL UNIVERSITY.

course at least one term is devoted to original investigation or special research, the results of which are embodied in a thesis.

In addition to this is a post-graduate course, which is devoted to experiments and special research.

The collection of apparatus available for experimental purposes has been largely increased during the past year, and new apparatus is purchased from time to time as needed. A complete list would be out of place in this description, but a few words regarding the more important apparatus will serve to show the facilities possessed for instruction in experimental engineering.

The laboratory is equipped for commercial testing as well as for educational purposes. While commercial testing is primarily of value only to the persons for whom the test is made, incidentally it is found of great value educationally, as giving variety to the laboratory practice and showing the practical nature and the usefulness of experimental work, and it is consequently solicited for the laboratory. Such income as may be obtained from that work is largely or entirely devoted to extending the laboratory plant or in scientific research.

The laboratory for strength of materials has in its equipment one Emery testing machine of 60,000 pounds capacity, of especially fine workmanship, having been built by Yale & Towne for the purpose of standardizing the parts of the regular Emery machines, and recently presented to the university.

Besides this there are eleven other testing machines, ranging in capacity from 300,000 pounds, among which are one Olsen testing machine of 300,000 pounds capacity, of which an illustration is shown. The stress is applied by means of gear or friction wheels, in either direction, and rapidly or slowly as required. This machine is adapted for tension, compression, or transverse strains, and is provided with the new autographic device for which Mr. Olsen was awarded the Cresson medal by the Franklin Institute of Philadelphia in 1891. It is used in the laboratory principally for commercial testing and specimens too large for the capacity of the other machines.

The Riehlé 200,000 pounds testing machine is a power machine, with gearing very similar to that of the Olsen 300,000 machine, and is especially adapted to the testing of long specimens in tension, transverse, or compression.

One Riehlé 100,000 pounds testing machine can be used for tension, compression, or transverse tests. The stress is applied by power and can be applied rapidly or slowly, at will, or entirely relieved by means of suitable clutches; the chain of gears which is driven from a countershaft receiving its motion from the line-shaft.

A Fairbanks 50,000 pounds testing machine is used for tension only. Stress is applied by power and can be exerted rapidly or slowly by means of a change of gear. The machine can be reversed by power by running with open belt. Delicate adjustments of stress and tests of small specimens can be made by hand, the belt being thrown off and a handle inserted into the driving pulley. The stress is measured with a single poise on a scale-beam graduated with two scales for poises of differing weights corresponding to maximum loads of 51,000 and 17,000 pounds.

A Riehlé hydraulic testing machine of 50,000 pounds capacity is adapted for tension, compression, and transverse tests. Stress is exerted by a modified form of hydraulic press and is measured on a double scale-beam.

A Riehlé hydraulic testing machine of 40,000 pounds capacity, which differs in design from that last described only in the arrangement of the weighing device. The stress is measured by a differential steelyard provided with a sliding poise and a set of weights, which are hung at the end after the manner of common platform scales.

Two Olsen testing machines each with a capacity of 16,000 pounds. Both machines can be used for either tension, compression, or transverse tests.

One Fairbanks transverse testing machine of 10,000 pounds capacity is used for experiments in flexure. Bars up to 6 feet long can be placed in this machine. The test-bar rests upon two cylindrical supports and is deflected by a pressure-screw worked by a hand-lever which



THE FOUNDRY.—SIBLEY COLLEGE, CORNELL UNIVERSITY.

engages with the milled head of the screw by means of a pawl which can be set to apply to or relieve the pressure. Stress is measured on a scale-beam in the usual manner.

Thurston's autographic recording testing machine is designed for torsion tests and is adapted to test-pieces of standard form and dimensions. Stress is applied by a worm and wheel and is autographically recorded together with the corresponding strain on a diagram sheet stretched over a brass drum.

Heisler's impact testing machine, by means of a heavy bob, strikes a blow upon a test-bar placed on two supports bolted to a heavy anvil. The blow is measured by the product of the weight of the bob into the height of the fall. The latter is indicated on an arc upon which slides the tripping device for holding the bob at the desired displacement.

Measurements of elongation are made by the aid of two very accurately cut screws termed micrometers, which by means of a milled head can be turned through a minute portion of a revolution, with a corresponding advance of the point of the screw.

These are supported by a framework which clamps to the specimen near each end. The frame must support the micrometers at equal distance from the specimen and in the same plane with it, it must remain securely fastened during the test or a portion of it, be capable of easy removal when necessary, and must exert no injurious effect on the specimen.

The extensometers in common use in the laboratory consist of two frames, which can be set by hooks, or by an external gage, at distances exactly eight inches apart, and are provided with two micrometers, made for the laboratory by Brown & Sharp.

Two Henning extensometers are also used, which differ from the others principally in the form of the micrometers and the clamps for holding to the specimen.

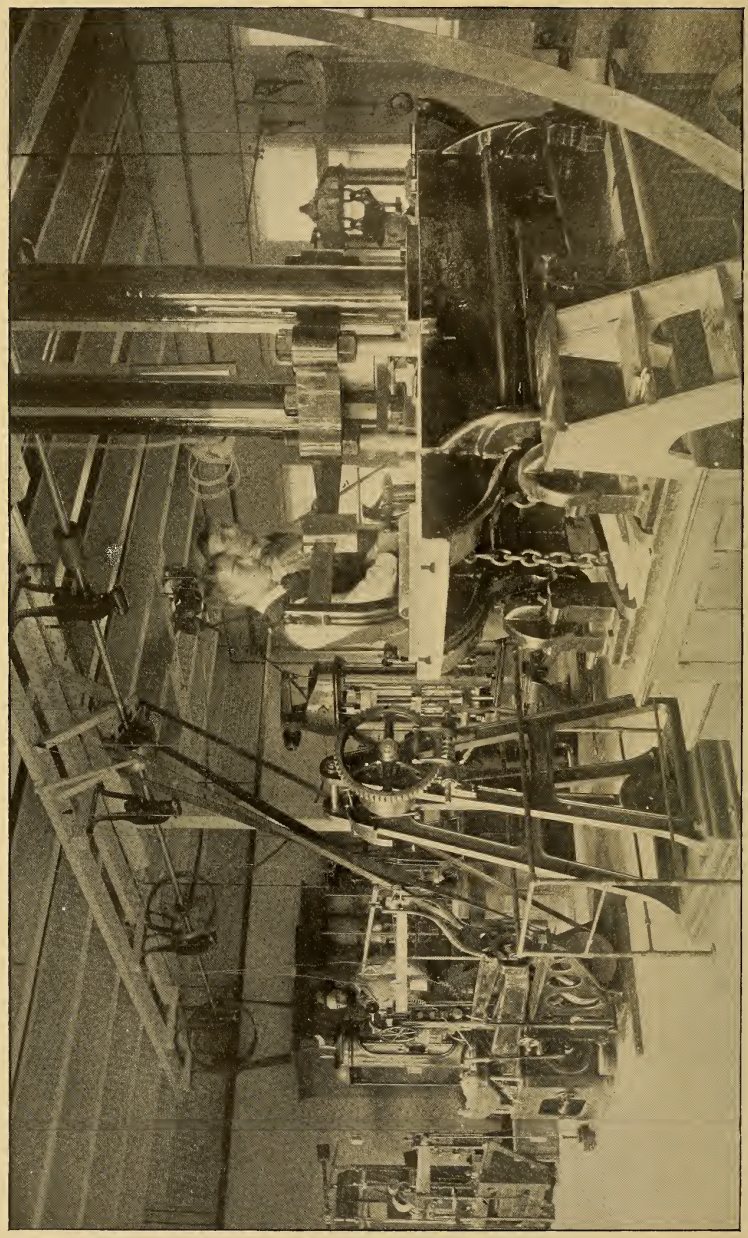
The hydraulic laboratory is equipped with stationary and portable weirs, nozzles, and Venturi tubes, by means of which the flow of water can be measured. The hydraulic machines to which the students have access for experimental purposes consist of several small water-motors, centrifugal and rotary pumps, and hydraulic ram, in rooms of the laboratory, and in addition they have access to the hydraulic machinery used for power purposes and for the water-works. This machinery consists of three turbine water-wheels, respectively of 50, 75, and 100 horse power, each working under a head of 45 feet. The flow of water can be measured by a large weir, and the power delivered either by a brake or by a transmission dynamometer. The pumping for the water-works of the university is done by two pair of duplex water engines, and these are also available for experimental purposes.

The laboratory for the measurement of friction is equipped with three of Thurston's machines for the determination of the coefficient of friction, and one of Bouldt's oil-testing machines for the testing of cylinder oils, and apparatus for the measurements of the viscosity, chilling points, and flashing points of various oils.

The laboratory for the measurement of transmitted power is supplied with several dynamometers, having a capacity ranging from one-half to 160 horse-power each. The belt-testing machine used in the experiments were made by Mr. W. Lewis, of Philadelphia. There are also several patterns of the Proney brake.

For experiments with compressed air the laboratory is supplied with two air-compressors, a Westinghouse air-brake outfit, and a rock drill. With heating and ventilating apparatus a number of experiments have been made, but no systematic course has been laid out.

The laboratory of steam engineering is the most important, from its relation to the motive power, in principal use. This is located in two rooms remote from the principal laboratory building, but adjacent to the boiler plant which supplies the university with both heat and power. Because of the installation of a large experimental engine, this laboratory at present is in a demoralized condition, and cannot be shown in the illustrations. The plant consists of two straight-line engines of about 30 horse power each, a Lansing compound engine of 70 horse power, an Ideal engine of about 30 horse



LABORATORY OF STRENGTH OF MATERIALS,—SIBLEY COLLEGE, CORNELL UNIVERSITY.

power, a small plain slide-valve engine, a surface condenser, several steam pumps, Rider and Ericsson hot-air engines, Otto, Broyton, and Otto-Lorgen gas engines, a large collection of calorimeters, and of injectors, apparatus for flue gas analysis, and for standardizing steam gages and indicators.

The experimental engine is a triple-expansion engine with Corliss valve-gear built by the E. P. Allis Company of Milwaukee, Wis., and designed especially for the university by Edwin Reynolds. It consists of three cylinders, each 36-inch stroke with diameters respectively of 12, 16, and 24 inches. The engine will give about 200 horse power and will be so arranged that it can be run as a simple engine, as triple-expansion or compound, condensing or non-condensing, with or without steam jackets as required. The engine occupies with its accessories a floor space of 36 by 40 feet, and will be in running order about the first of January, 1892.

The students taking the courses in Sibley College have increased from about 80 in 1885 to nearly 600 the present year. Of this total number somewhat over one-third are registered for laboratory work. The total amount of floor space available for laboratory purposes amounts to 4000 feet in the mechanical laboratory structure, 1600 feet in the room for the large experimental engine, and about 1000 feet in the rooms for the smaller engines. Considering the space needed by each student for work of this character, the crowded condition of the laboratory at once becomes apparent, and indicates what is certainly the pressing need of the Sibley College laboratories at the present time, and that is a new building.

THE smallest engine we have any record of is that made by D. A. Buck, of Waterbury, Conn., says the St. Louis *Republic*. The engine, boiler, governor, and pumps all stand on a space of 7-16 of an inch square and are about 5/8 of an inch high. The engine has 148 distinct parts, held together by 52 screws. Three drops of water fill the boiler to overflowing. The diameter of the cylinder is 1-26 of an inch; the length of the stroke 3-32 of an inch. The whole engine weighs but three grains, not including base-plate.

Levi Taylor, an ingenious mechanic of Indianola, Ia., has constructed an engine almost equal to the Waterbury wonder. This pigmy was on exhibition at the Centennial, at Philadelphia, in 1876.

It is built on a twenty-five cent gold piece, the whole outfit weighing but a fraction over three grains. It must have been quite a contrast to the enormous Corliss engine when on exhibition in the same building.

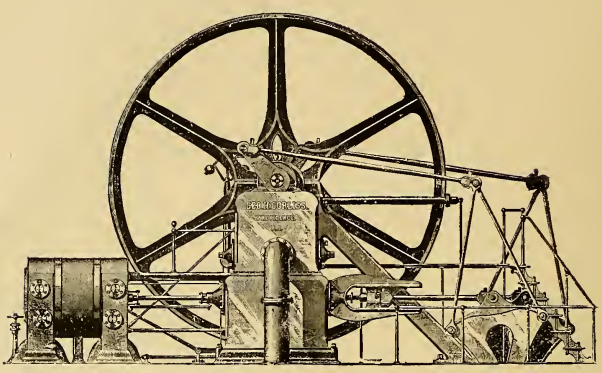
Taylor's engine, while not as small as that made by the Waterbury mechanic, is a wonder that will be better appreciated when the reader is informed that it would take 146 such engines to weigh one ounce avoirdupois.

REGARDING boiler accidents, Inspector-General Dumont, of the Steamboat Inspection Service, calls attention in his annual report to the fact that only six accidents occurred during the year to marine boilers and pipes, which involved the loss of fourteen lives.

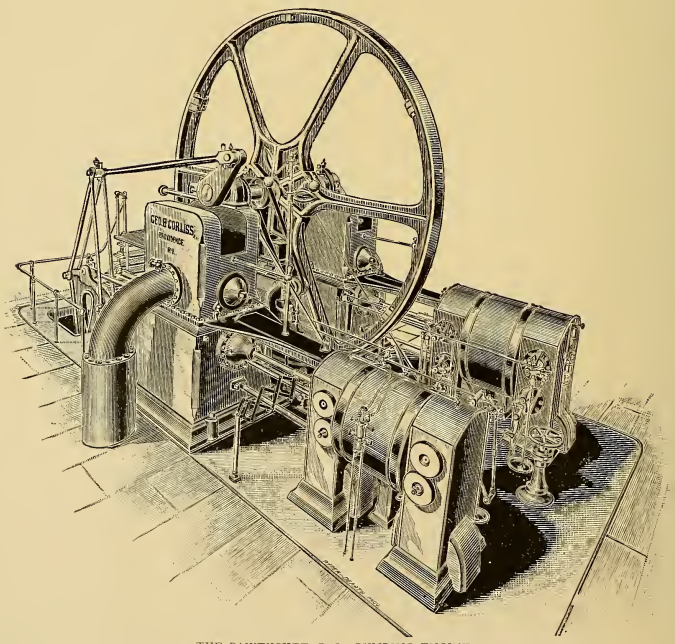
He contrasts this with the published report of a steam-boiler insurance company, showing that in 1890 the accidents to other boilers numbered 198, resulting in 206 persons being killed and 342 injured. The difference is attributed to careful inspection, as 600,000,000 passengers were exposed to the chance of the explosion of more than 10,000 boilers in use on 7404 steam vessels.

Out of a total of 1991 pilots examined, forty-four were rejected on account of color-blindness.

Of the thirty-three accidents to vessels, sixteen were collisions, six from fire, and the others from explosions, sinking, etc. The number of lives lost was 338, an increase of ninety-three over the previous year. But the increased fatality is more than accounted for by the loss of ninety-eight lives on the steamer *Sea Wing*, destroyed by a cyclone on Lake Pepin in July.



THE PAWTUCKET, R. I., PUMPING ENGINE. SIDE VIEW.



THE PAWTUCKET, R. I., PUMPING ENGINE.

THE INFLUENCE OF STEAM JACKETS.*

By William Kent, M.E.

PAPERS under the title of "Influence of the Steam Jackets of the Pawtucket Pumping Engine" have been presented to the American Society of Mechanical Engineers by Professor James E. Denton and by Professor D. S. Jacobus.

In these papers different tests of the Pawtucket pumping engine have been described in great detail. Concerning the influence of the jackets upon the economy of the engine, the leading conclusion of Professor Denton was that "the most that can be claimed for the jacket is that it probably caused no loss, and may possibly have caused a saving, not exceeding 3% of the total consumption." Professor Jacobus's conclusions, made after a comparison of his own tests with those of Professor Denton, and of Mr. John Walker, the superintendent of the water-works, are: "(1) The effect of jackets on the form of the expansion curves of both the high- and low-pressure cylinders is so small that the errors involved in the most accurate measurements of the indicator diagrams make it impossible to show any difference in the laws governing the same.

"(2) The economy of the plant when working under the three sets of conditions is about 1.7% in favor of using the flue reheater, and 2.5% in favor of using both jackets and flue reheater, over that obtained when neither the flue reheater nor jackets are used."

As the results and conclusions in these two papers have been a surprise to many engineers, and as in their discussion some doubt was expressed upon the accuracy of the observations or of the apparatus used in the tests, Professor Denton desired that further tests of the efficiency of the steam jackets be made by an observer other than himself, and that in these tests all the possible precautions should be taken which had been suggested by the discussion of the papers above mentioned. At his request the writer consented to make a series of tests jointly with Professor Jacobus, and the object of this paper is to place the results of these tests on record.

Tests were made by us on May 14, 15, and 16. The indicator diagrams were taken by Professor Jacobus and the writer simultaneously, four indicators being used on the steam engine, one on each end of each cylinder. When diagrams were taken from the water cylinders at the same time, they were taken by the engineer of the pumping-station. All other observations were taken by ourselves. On Tuesday, May 19, Professor Jacobus returned to Pawtucket and made another test under the same conditions as that of May 14.

Since the tests were made the original records have been in the hands of the writer, and he has calculated from them the average results shown in the appended tables.

These results show the effect of the steam jacket on economy, within the limits of accuracy of the apparatus, of the observations, and of the measurements of the indicator diagrams. All the tests were made under uniform conditions as to steam pressure and work done, and the same indicators were used in the same positions in each test; instrumental corrections will not therefore change the relative results, nor the percentage of gain made by the steam jackets. As all of the instrumental errors are quite small, however, none of them exceeding 2%, and as those in the case of the indicators, which were accurately standardized, were found to balance each other, the error in the total horse power developed, and in the economy of the engine, or steam consumption per horse power per hour, due to constant instrumental errors, is probably not over 1%.

No attempt has been made to study the effect of the steam jacket upon the law of the expansion curves in the two cylinders, nor upon cylinder condensation in the cylinders.

* Paper read before the American Society of Mechanical Engineers.

Professor Denton in his paper lays great stress on the errors of indicator diagrams and their measurement, so that he says the apparent saving of from 0.13 to 0.35 lbs. of steam per horse power per hour is within the limit of error to which the determination of indicated horse power and cut-offs are subjected, so that he will not admit more than that the jackets only *possibly* caused a saving. It seems to the writer, however, that the variable errors in diagrams taken by several different indicators, and by different observers after proper corrections for known errors of the springs, should be expected to tend to balance each other, and that although the actual error of any single diagram may be 3%, yet if a series of diagrams during a long test show an average result of from 0.13 to 0.35 lbs. saving, or from less than 1 to less than 3% in favor of the steam jackets, that result, small as it is, should be accepted as highly probable, rather than merely possible, until other results overthrow it. Professor Jacobus's tests, reported in his paper, also have the same tendency to show uniformly a very slight saving by the use of the jackets, and the tests now reported confirm the results both of Professor Jacobus and Professor Denton, in showing that the jackets do give a saving, but that the saving is very slight, ranging from about 1 to less than 4%.

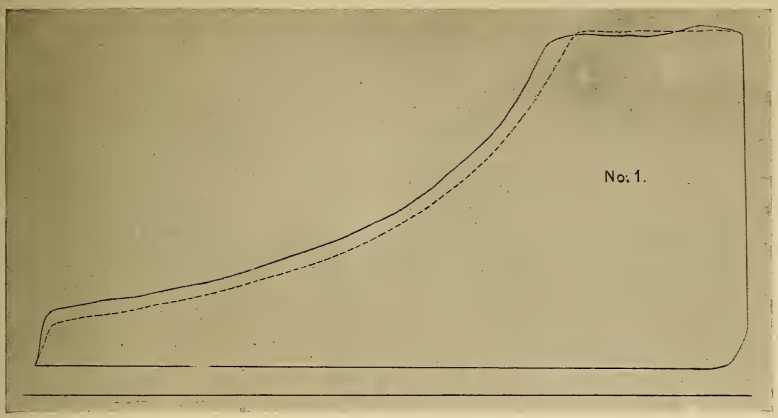
The engine, of which illustrations are shown on page 116, is described in Professor Denton's paper, but a brief description may be repeated here. It is a horizontal cross compound engine, steam cylinders, 15 and 30⅛ inches bore; water cylinders, 10.52 inches; stroke of all pistons, 30 inches; clearance, high-pressure cylinder, 4%; low, 3.7%. Diameter of rods, 2¾ inches. Ratio of volumes of cylinders, 4.085. Average cut-off in high-pressure cylinders, one-fourth, and in low, one-third. Jackets envelop the barrels, but not the heads, of both cylinders, and steam of full boiler pressure is used in each. The heads are not jacketed, but contain passages leading to and from the ports. The condensed steam from the jackets is pumped into the feed-pipe at a point between the boiler and hot well. The condensed steam collected in the receiver is received in a trap, and continuously pumped through a heater placed in the chimney flue, and thence returned to the top of the receiver. Out of a total of about 155 pounds thus circulated per hour, in actual work, one-third only is evaporated and returned to the receiver as steam; the other two-thirds gradually accumulate in the receiver and are blown to waste every three hours.

The conditions under which the tests of the four different days were made are as follows:

In the first test, on Thursday, May 14, the jackets on both cylinders were in use, as also was the reheater in the chimney, through which was passed the water that collected in the receiver.

To prove the absence of air and the thorough heating of the jackets by live steam, a thermometer, in a mercury well, was inserted into the upper part of each jacket. These thermometers registered uniformly 346° to 350° Fahr., or from 5° to 8° less than a thermometer in the steam pipe, or just about the temperature due to the pressure of the steam. Pet cocks were also let into the upper part of the jackets, and these were frequently opened to a very slight extent, when instantly steam appeared, there being not the slightest evidence of air at any time.

In order thoroughly to drain the condensed water from the jackets, pipes were led from the lowest points down to the cellar, beneath the engines. Water gages were inserted in a horizontal extension of these pipes, and an assistant kept constantly at the exposed extension of these pipes, who opened a cock and discharged the accumulated water through a cooling coil into a pail whenever it reached a certain level in the water-gages. This water was weighed from time to time, and it weighed 35 pounds per hour for the high-pressure cylinder, and 77 pounds per hour for the low-pressure cylinder, a total of 112 pounds. The object of cooling the water was to prevent loss by evaporation. This was accomplished by passing it through two Nason feed-water heaters, through the steam spaces of which cold water was circulated. A water-gage



AVERAGE CARDS MAY 14 AND 15.

Full Line, 3.52 P.M., May 15, Inside End, M.E.P., 61.50. Jackets off.
Dotted Line, 3.35 P.M., May 14, Inside End, M.E.P., 58.75. Jackets on.



AVERAGE CARDS MAY 14 AND 15.

Full Line, 3.52 P.M., May 15, Outside End, M.E.P., 58.75. Jackets off.
Dotted Line, 3.35 P.M., May 14, Outside End, M.E.P., 57.50. Jackets on.

was also attached to the pipe leading from the reheater to the receiver, to indicate whether any water came back from the reheater in evaporation. This pipe collected a very small amount of water, so that it had to be blown off only three times during the day.

The engine was run under these conditions nearly five hours before the taking of records, begun at 10.45 A.M., so as to have everything heated to normal conditions.

The water fed to the boiler was weighed in a tank upon a platform scale, from which tank it was discharged from time to time into a second tank, from which it was then fed by a pump to the boiler. At the end of each half hour the water was brought to as nearly as possible the same level in this second tank, and the weight in the first tank recorded, corrections being made for the very slight variations in the water level in the second tank, and the height of the water in the three vertical tubular (Corliss) boilers was recorded. Corrections were made in the water record for variations in the water level. The apparent irregularity in the water record of water consumption per half hour is due, to some extent, to the fact that the jackets were not in use, and whatever water collected in the receiver passed into the low-presssure cylinder, as the reheater also was not in use. The jackets were opened at their lowest points to prevent any possible presence of water in them. The thermometers in the jackets registered 250° to 260° Fahr. in the high-pressure, and 196° to 198° in the low-pressure cylinders.

At the third test, Saturday, May 16, the conditions of the first test were repeated, except that the water condensed in the jackets was not caught and weighed, but was allowed to pass into the feed-pipe between the tank and the boilers, as in the ordinary way of running the plant. On this account an addition of 112 pounds per hour, which was the amount of condensation determined on Thursday, was added to the tank record of water used.

On the fourth test, Tuesday, May 19, the conditions were in all respects the same as at the first test. The water condensed in the jackets was 36.2 pounds in the high-pressure cylinder, and 75.2 pounds in the low, or 111.4 pounds total.

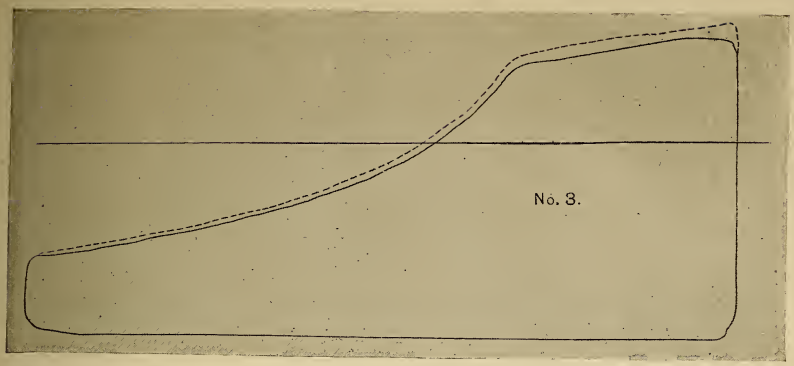
The following table gives the principal results of the tests:

	Jackets in use, May 14.	Jackets off, May 15.	Jackets in use, May 16.	Jackets in use, May 19.
Engine-room temperature, degrees Fahr.	83.3	83.0	83.05	80.3
" " barometer, inches	30.111	30.180	29.90	.....
Feed-water temperature, Fahr.	63.8	63.9	80.4	60.5
Boiler pressure, lbs. above atmosphere	123.5	123.5	123.1	123.0
Steam pressure in high-pressure jacket	121.5	0	121.1	121.0
Temperature of steam due to boiler pressure	351.9	351.9	351.7	351.6
" " " 2 feet from steam-chest.	355.1	362.8	359.8	355.0
" " " high-pressure jacket	348.0	257	349.	349.7
" " " low- " "		197		
Receiver pressure, lbs. above atmosphere	9.1	9.2	10.0	8.8
Vacuum by gage, inches	27.9	27.3	27.1	28.3
Revolutions per minute, average	48.0	48.0	48.05	48.3
Horse power, indicated "	142.90	140.78	139.95	141.91
Total water pressure, including suction, lbs., average	119.37	117.51	115.96	118.74
Water condensed in jackets, h.p. per hr., lbs.	35	.....	.....	36.2
" " " " h.p. " " "	77	.....	.....	75.2
Steam consumption per hour, average	1,956	2,007	1,965	1,980
" " H.P. per hour	13.687	14.256	14.041	13.952
Saving due to jackets, per cent	3.99	.....	1.51	2.13

Saving due to jackets, average of 3 tests, 2.54 per cent.

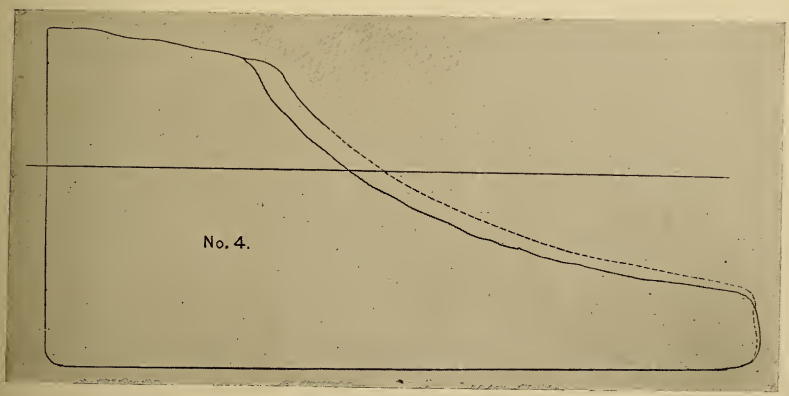
with the same amount of water in a vertical boiler the apparent water level may vary on account of differences in the condition of the fire. If records were taken at less frequent intervals, the apparent irregularity would decrease.

On the second test, Friday, May 15, the indicator diagrams Nos. 1 to 4 inclusive are selected from those taken on May 14 and May 15 to represent the average cards of these days, the mean effective pressures of these cards corresponding nearly to the average mean effective pressures of all the cards taken



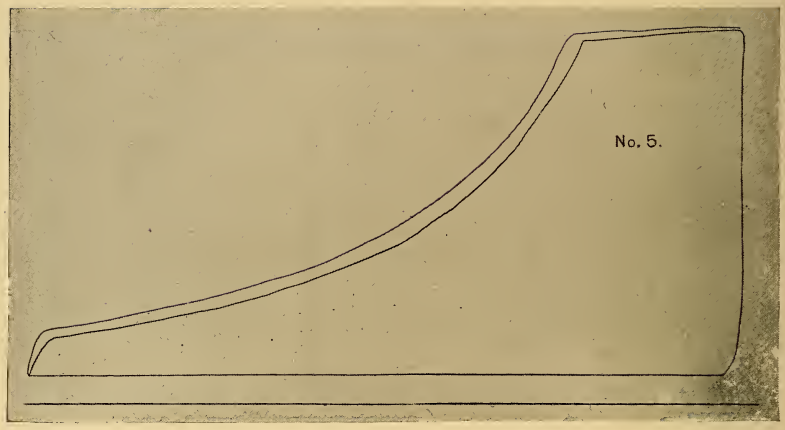
AVERAGE CARDS MAY 14 AND 15.

Full Line, 3.52 P.M., May 15, Inside End, M.E.P., 12.25. Jackets off.
Dotted Line, 3.35 P.M., May 14, Inside End, M.E.P., 12.65. Jackets on.

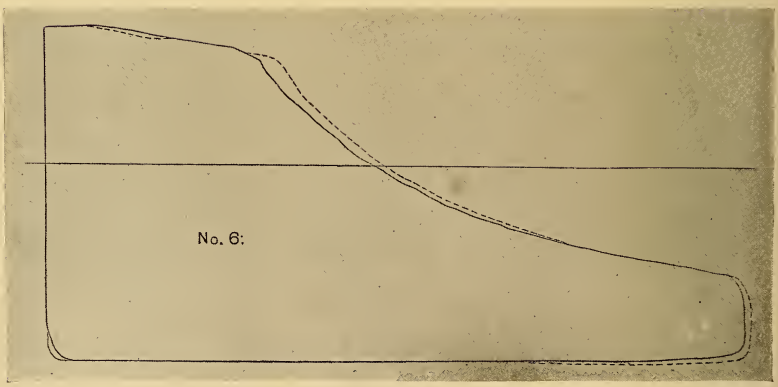


AVERAGE CARDS MAY 14 AND 15.

Full Line, 3.52 P.M., May 15, Outside End, M.E.P., 12.85. Jackets off.
Dotted Line, 3.35 P.M., May 14, Outside End, M.E.P., 13.75. Jackets on.



MAXIMUM AND MINIMUM CARDS MAY 14. INSIDE END.
Maximum, 12.35 P.M., M.E.P., 61.50.
Minimum, 5.02 P.M., M.E.P., 55.25.



MAXIMUM AND MINIMUM CARDS MAY 14. OUTSIDE END.
Full Line, 1.10 P.M., M.E.P., 13.30.
Dotted Line, 4.55 P.M., M.E.P., 14.

during these two days. For comparison, Diagrams Nos. 5 and 6 are also given, from the cards of May 14, to show the maximum variation in the cards taken on one day when the jackets were in use. This shows that the differences between the average cards of the two days which gave the greatest difference in economy, the jackets being used the first day and not used the second, are no greater than what appear to be the accidental differences between cards taken on the same day and under the same conditions. An inspection of the tables of mean effective pressures of all the cards taken will show large variations in mean effective pressures in cards taken near the same time, and when the work done, according to the water-pressure gages, was the same. It is noticeable also that the outside end of the cylinder will sometime show the greater mean pressure than the inside end,* and sometimes the reverse. The causes of these fluctuations in the energy developed in the cylinders are not apparent in all cases, but are partly due to the action of the governing device, which does not produce precisely the same variation in cut-off at the two ends of the cylinders for a given variation of load or of steam pressure.

The tests above reported, taken in connection with those previously reported, I think prove that in the use of the Pawtucket pumping engine the use of the jackets gives a saving of between 1% and 4%, but they do not lead to any more general conclusion than that jackets may be expected to give this saving in a cross compound Corliss engine of 140 H.P., running at about 50 revolutions per minute, supplied with dry steam of 125 pounds gage pressure, and cutting off at about one-quarter stroke in the high and one-third stroke in the low-pressure cylinder. Before this conclusion can be expanded to apply to other engines, there should be tests made with equal precautions and refinements to those made with the Pawtucket engine, on such other engines, with different dimensions and different conditions, such as pressure of steam, moisture, or superheat in the steam, speed of revolution, number of expansions in the two cylinders, etc.

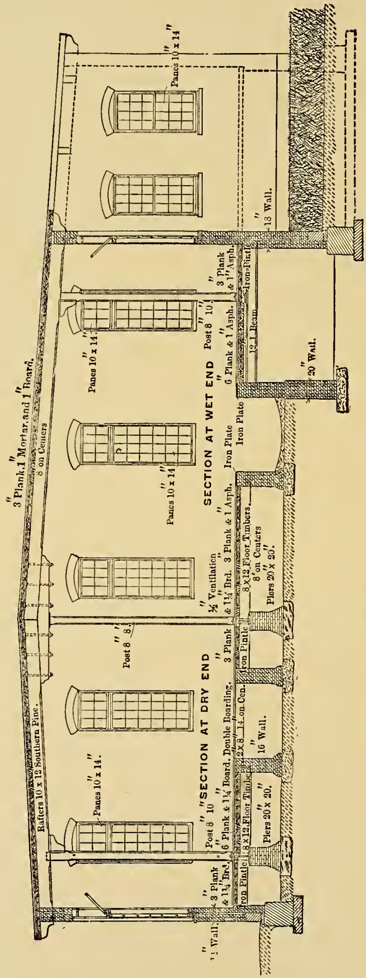
In view of the rapidly increasing use of compound engines with high pressures and higher speeds than the Pawtucket engine, it is much to be desired that a series of tests should be undertaken in order to learn whether in such engines the steam jacket causes any saving sufficient to compensate for its extra cost.

It is gratifying to be able to confirm the general results as to the economy of the Pawtucket engine, which has been found by Professors Denton and Jacobus, as well as those that have been made by Mr. Walker, the engineer of the waterworks. It is worthy of notice, also, that this engine, built nearly fifteen years ago, has not yet been surpassed in economy by any two-cylinder compound engine, nor as a pumping engine has it yet been surpassed by any type of engine whatever.

* By the inside end is meant the end of the steam cylinder nearest the pump cylinder, corresponding to the "crank end" in an ordinary engine.

PROCESS OF MAKING CHROME STEEL.

CHROME steel is made in crucibles, by a remelting process, from ordinary Norway iron and a given quantity of chromium, says the *Iron Trade Review*. The product, which is rolled from ingots in the ordinary commercial round, square, and octagon bars, has an insertion of a layer of chrome steel hidden between an inner and outer layer of iron; the combination plates of 5-ply thickness are prepared in the same manner. The completed material is said to be the hardest steel known, and easily resists the drilling, cutting, or boring tool of the burglar, hence chrome steel bars and plates are extensively used in making burglar-proof safes and vaults, and in the construction of jails and prisons.



PAPER MILL,—SECTION OF MACHINE ROOM.

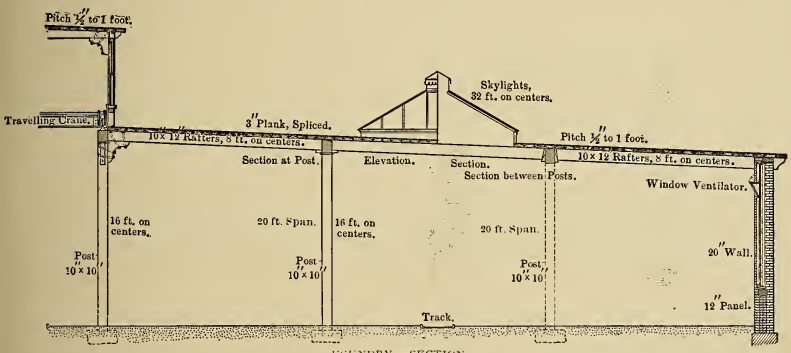
METHODS OF REDUCING THE FIRE LOSS.

By C. J. H. Woodbury,

Vice-President Boston Manufacturers' Mutual Fire Insurance Company.

NO. II.

FOR establishments on cheap, level land, especially where the stock is heavy, one-story buildings have proved to be more economical in cost of floor area, supervision, moving stock in process of manufacture, and repairs to machinery, many kinds of which can be run at greater speeds than when in high buildings. Such buildings are readily warmed and ventilated, and heavy plank roofs are free from condensation in cold weather; dust will wear machinery, unless covered by flooring. Floors made by laying sleepers on six inches of pebbles, tarred when hot, then two inches tarred sand flush to top of sleepers, and covered by double flooring, have remained sound since 1865; but double flooring at right angles can be laid on the concrete without the use of sleepers, and nailed together. It is usually preferable to secure nailing strips to stakes four feet apart each way and driven to grade, concrete flush to top of strips, and lay single 1½-inch flooring.



FOUNDRY.—SECTION.

the large window area reduces the hours of artificial illumination. Forced circulation of heated air is a very desirable method of heating a mill, being economical as to maintenance and repairs, and thoroughly under control. Overhead steam pipes are very satisfactory, if used in the ratio of one foot of 1¼-inch pipe to 70 cubic feet of air.

It is convenient in machine shops to provide rails extending the length of the building under the roof timbers, for the purpose of clamping countershafts to these rails as may be desired.

Floors over an air space or on cement are subject to dry rot. Asphalt or coal-tar concrete is softened by oil, and the

Piers reach to roof timbers, and light walls to window-sills are finished with slope on inside. In some instances it is preferable to build brickwork up to window-sills, and support the roof by square posts filling the spaces between the windows, and which are secured to the beams by timber knees or iron brackets. Large windows are placed high, and the sashes separated by a mullion. Lower sashes should be stationary and glazed with rough glass, with transom sash or window ventilators above. If the light is too strong, apply to glass white zinc and turpentine.

The swinging sashes in monitor can be moved in groups by bell cranks from

a shaft turned by an endless screw. The connection should not be rigid, but flexible steel links or springs should be introduced to provide for the sashes being out of line, and also to close them with an amount of yielding pressure sufficient to prevent any jarring.

Wooden mill columns, Southern pine or oak, safely sustain loads of 600 pounds per square inch: a square column is stronger than a round one of the same diameter. They should have a 1½-inch core bored from end to end, and two half-inch holes through the column near to each end.

The columns should be securely held at each end, the base resting on iron plates projecting above the floor level, and the caps at the top bolted to the roof beams.

Double or solid timbers of Southern pine support the roof plank, and the ends pass through the wall, and are finished as brackets to the cornice. The beams are anchored to plates in the walls by means of tongues which project into grooves across the lower side of the beams. Beams should not be painted or varnished until thoroughly seasoned.

The roof plank should be two bays in length, breaking joints every three feet. There is no need of gutters, but a concrete walk, sloping toward drains, will take the water from the roof. Do not drive nails upward into the roof plank, as moisture will condense and drop from the heads.

The form of paper machine room, as illustrated on page opposite, with thick, solid roof, has proved to be very successful in practical operation, being comfortable and free from vapor and easily ventilated.

A foundry roof, as illustrated on page 125, has no lodging-place for dust if a sloping cover is placed on the small portion of beams under the skylights. The stringing beams hold the alternate roof beams by iron stirrups, and should be 10 by 15 inches. The roof plank should be slightly raised at the left of the skylights.

The actual hazards from the tools and machinery used in manufacturing processes are so many that there is no opportunity for more than passing reference to some of those of quite frequent occurrence.



MACHINE SHOP.—ELEVATION.

In all machinery hot journals are a prolific source of fires, and protection is to be secured by free lubrication with oil suited to the especial service required of it. In many instances it would be a good investment to place long lines of heavy shafting in pillow blocks on masonry piers, rather than in hangers or in harness frames. This particularly applies to the methods of transmitting power to the beating engines in paper-mills.

Taking the dangers from machinery in the order of their causes, those from prime movers require the first consideration. The dangers from fire in boiler-rooms are few, the risk being well

understood and is looked out for accordingly. If other perfectly well-known, although not as apparent, possibilities of fire were as carefully guarded, there would be a great diminution in the number of fires.

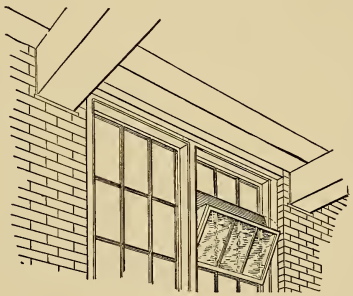
The fires from the spontaneous ignition of bituminous coal are very difficult to conquer. The explosion of gas generated by the hot coal frequently causes serious damage in addition to that from the direct combustion of the coal. Such fires are prone to occur when least expected and to cause unwarrantable large damage. The cause of the spontaneous ignition of coal is undoubtedly the heat produced by the chemical changes occurring in the inorganic sulphur compounds abounding in the coal; these changes being favored by time, dampness, and pressure. While it may be assumed that within certain limits the percentage of such inorganic sulphur compounds would be a measure of the hazard of spontaneous ignition likely to arise from any quantity of a given coal, yet there are difficulties in the way of an application of any such assumption. The sulphur which causes the damage is not that of the average of the whole mass, but the maximum in any lump of coal exposed to favorable conditions; and, secondly, the analyses generally give the total percentage of sulphur without separating the organic from the inorganic compounds.

Returning to the more practical features of the matter, bituminous coal should not be stored under valuable buildings, nor in contact with timber. When a lot of coal is used up, the coal-shed should be thoroughly swept out before a new supply of coal is added. If the depth of coal exceeds eight feet, iron rods should be pushed to the bottom and examined every day, as the warmth of any heating within the pile is conducted to the protruding end of the rod, and thus an opportunity is given to shovel over the coal before it actually reaches the ignition stage.

There are no precautions to be suggested for anthracite coal storage, as the hazard is almost nominal.

The general use of crude petroleum for fuel is too new to furnish a history, but the record thus far has contained accounts of many accidents, principally in connection with faulty methods of storage. The petroleum should be securely stored in ventilated, covered, iron tanks, placed below the point of consumption, and where the oil cannot endanger any property in event of breakage. At the point of consumption the oil is attended with the hazards of other gaseous fuel, particularly at the instant of lighting, and in like manner it is necessary to apply the flame before turning the oil spray on to the furnace.

The crude petroleum used for fuel has a flashing point of 16° to 35° F., giving off inflammable vapors at about the freezing point of water. The reduced oil has been "treated" in order



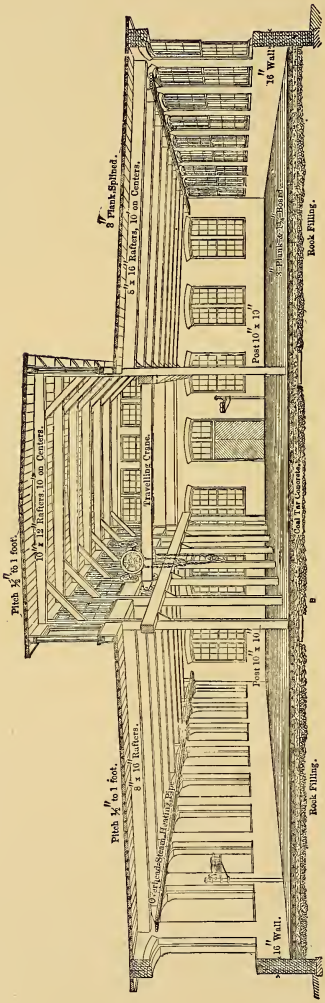
WINDOW VENTILATOR.

to remove the readily volatile material, and its flashing point raised to 125° and upward, sometimes reaching 300° F. It is much safer than crude petroleum, but very difficult to pump in cold weather.

In the steam engine room, hazards are not due to the machine, but to neglected oily waste and similar reprehensible matters.

Water-wheels are subject to dangers in connection with the wearing away of the wood step, which will occur at odd intervals and without any previous notice; the alteration in the height of the turbine shaft frequently causing the bevel gears to strike fire, thus igniting the grease.

The distribution of power has been attended with many and severe fires, generally resulting in what is known as a total loss. The greater part of this de-



SLOW-BURNING CONSTRUCTION.—ONE-STORY MACHINE SHOP.

struction may be avoided by building a belt tower in the mill, opening toward the engine room and covered by a glass roof with wire netting beneath the glass. The driving is in this tower, and the power is transmitted by shafting passing through holes in the wall of the tower.

All machinery which throws a waste product in a dust-room, as cotton pickers, buffing machines, and napping machines, frequently ignite such fluff, and the fire returns to the room where it started through the flue or trunk of some other machine not in operation, or the flames burst from several of the machines when they are stopped at noon or night. Such mishaps are materially reduced by placing light swing dampers at the ends of the flue where they are kept open by the current of air from the blowers of the machines in operation, and at other times are shut.

The floor under machines liable to scatter oil should be protected by sheet metal, particularly in the case of woolen cards, mule-heads, and in some instances electric motors.

The limitations of this article will not allow further allusions to the dangers from particular machines; but the principle of keeping them in the best operating condition is also that of keeping them in the safest condition, and no one is better fitted for the exercise of such care for the prevention of fires than those engaged in the practical attendance of such machines.

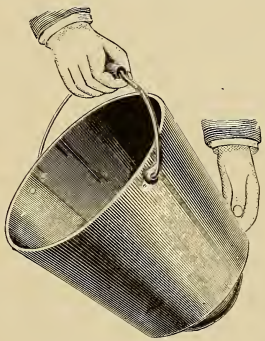
All methods for the prevention of fires fall so short of the ideal of immunity that there is a necessity for fire apparatus. The principle of defense of a manufactory against fire is that of self-protection by making the installation and management of the fire apparatus of such a grade as to be able to cope with the progress of any fire which can possibly occur. The merits of fire organizations have already been considered as essential to the service of fire apparatus.

Buckets of water are the most effectual fire apparatus. They should be kept full and distributed in liberal profusion in the various rooms of a mill, being placed on shelves or hung on hooks, as circumstances may require. In order to assist in keeping them for fire purposes only, they should be unlike other pails used about the premises, and in some instances each pail and the wall or column behind its position bears the same number.

It is a mistake to keep fire-pails in dry-rooms, as the water in the pails evaporates rapidly, and also in so doing interferes with the drying processes. The pails should be placed in some convenient situation near to the dry-room, where they will not oppose the drying process, and will also be more accessible in case of fire than when hung inside of a dry-room.

In unheated buildings the contents of fire-pails can be prevented from freezing in winter by adding chloride of magnesium to the water.

Galvanized iron pails are better than wood pails, and indurated fiber makes a very satisfactory pail, especially in places



A GOOD FIRE-PAIL.

around bleacheries, chemical pulp, or paper-mills, where corrosive fumes rapidly injure metal pails.

There are various expedients to insure the full condition of fire-pails, such as various floats, or electrical contrivances, or sealing over the top of the pail some thin sheets of impervious material; but the fact is that there is no fire apparatus so simple and effective as a pail full of water in good hands. All automatic devices are not above contingencies, and they lead to lowering the standard of personal espionage, which is the controlling principle in the administration of affairs.

Generally there is also need of casks

of water to furnish a further supply to the fire-pails.

Garden hose attached to a supply of water often constitutes a very useful portion of the fire apparatus. Any cocks in the nozzles should be fixed in an open position by striking a heavy blow on the handle of the plug cock commonly used in such fittings.

Automatic sprinklers have proved to be a most valuable form of fire apparatus, operating with great efficiency at fires where their action was unaided by other fire apparatus, particularly at night. In mill fires the average loss for an experience of twelve years shows that in those fires where automatic sprinklers formed a part of the apparatus operating upon the fire the average loss amounted to only one-nineteenth of the average of all other losses. If the difference between these two averages represents the amount saved by the operation of automatic sprinklers, then the total damage from the number of fires in places in which automatic sprinklers are accredited as forming a portion of the apparatus has been reduced six and a quarter million dollars by the operation of this valuable device.

Although there have been numerous patents granted to inventors of automatic sprinklers since the early part of the present century, yet their practical use and introduction has been subsequent to the invention of the sealed automatic sprinkler by Henry S. Parmalee, of New Haven, Conn., about twelve years ago. This device being the first, and for many years the only automatic sprinkler manufactured and sold, and actually performing service over accidental fires, to him belongs the distinction of being the pioneer and practically the originator of the vast work done by automatic sprinklers in reducing destruction of property by fire.

Although nearly or quite two hundred thousand Parmalee automatic sprinklers have been installed, their manufacture has been supplanted by other forms; and the total number of automatic sprinklers in position at the present time must be about two million.

In an automatic sprinkler system the sprinkler heads are attached to tees in pipes against the ceiling; the arrangement being such that there shall be at least a sprinkler to every one hundred feet of floor, some places requiring a still larger number of sprinklers and they should never be placed over 12 feet apart. There should be two sources of water-supply, with check-valves in the pipes leading into the sprinkler system, giving it the benefit of the greater pressure without the intervention of any personal act. If one of these supplies is furnished by an elevated tank, the minimum head from the bottom of the tank to the highest sprinkler should be not less than twelve feet.

The inability to withstand freezing temperatures is a defect in automatic sprinkler systems which has not been fully remedied by invention. There are many so-called dry-pipe systems, in which the water is kept from the system until fire occurs, when the heat which releases the sprinkler is presumed to actuate devices which open the main valves admitting water to the system. Such apparatus is always complicated; these systems have sometimes proved to be inoperative at fires, and have frequently been discovered to be out of order when examined. The attempts at making a solution of low freezing point, which should be non-combustible, and under the conditions of its use should also be non-corrosive, do not appear to have been successful.

Water is sometimes removed from automatic sprinkler systems during cold weather by pumping in air to a pressure sufficient to displace the water. This method demands a great deal of attention; and in case of a fire it requires even longer to discharge the compressed air from the pipes and throw water on the fire than would be the case with the usual dry-pipe system.

The only resource for automatic sprinklers in rooms liable to temperature below the freezing point appears to be to shut the supply-valve and slowly draw the water from the pipes late in the autumn and to admit the water in the spring. The valves should be in a place accessible at time of fire, and all persons liable to have any duties in the matter should be made acquainted with the necessity of opening such valves in time of fire.

The discharge of automatic sprinklers, including the resistance of the pipe fitting, may be represented by $Q = 0.6\sqrt{p}$, in which Q equals the discharge in cubic feet per minute, and p the pressure in pounds per square inch.

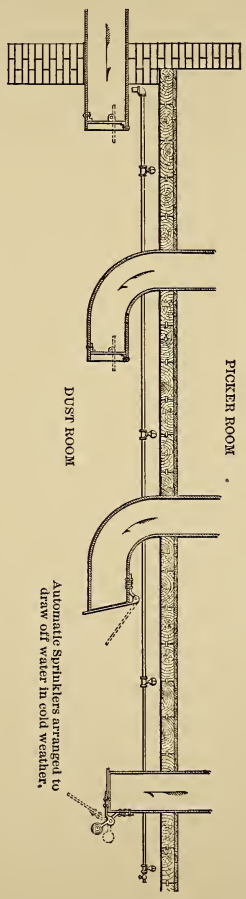
The following standard of sizes for pipes for automatic sprinkler installations is based upon the principle of using the nearest commercial sizes permitting a uniform frictional loss through the system :

Number of Sprinklers.	Diameter of Pipe.
115	4 inches
78	3½ "
48	3 "
28	2½ "
18	2 "
10	1½ "
6	1¼ "
3	1 "
1	¾ "

When automatic sprinklers were first introduced there were many apprehensions that leakage, and also excessive water discharges upon small fires, would be sources of damage. In England this opinion found expression in increased insurance rates in buildings where automatic sprinklers were installed.

Many automatic sprinklers have been made in such a manner as to impose unusual stress upon the fusible solder, which is a weak alloy possessing but little resilience, and therefore ill adapted to withstand the forces due to water pressure, water hammer, and what is sometimes greater than either, the initial tension in setting up the sprinkler to make it tight. It is not surprising that such sprinklers break or leak ; but among the score or more automatic sprinklers on sale it is easy to select several varieties, any one of which would impose but little risk of leakage from water pressure.

The logic of figures shows that this liability to damage is merely nominal in the case of well-constructed sprinklers. An association of underwriters who have given careful attention to the subject obtained the facts that out of 514,071 automatic sprinklers which had been in actual service on the average for five years, under a water pressure reaching in some instances one hundred and eighty pounds to the square inch, but averaging sixty-nine pounds to the square inch, there had been only fifty-eight instances of sprinklers leaking from water pressure, and three hundred and seventeen instances of leakage from other causes than fire, generally by accidents to the machinery or by careless-



ness of the employees ; the average damage from all these causes being $2.56 per plant per annum.

In testing the opening of automatic sprinklers, I employ two entirely differ-

ent processes, one being for the purpose of ascertaining the opening temperature of the sprinklers. The apparatus consists of an oven made out of a street-lamp, with a pipe entering at the top on which the sprinkler can be placed in a pendant position similar to that which it has when in use. A water pressure is obtained by connecting the pipe to a reservoir made out of a fire extinguisher, the upper part of which contains compressed air, the water being forced in at the bottom by a pump. In this manner the water pressure on the sprinklers can be controlled without shocks due to the action of the pump, and furthermore, when necessary it is possible to have a circulation of water in the pipe in order to conform to the condition which always exists in the operation of any sprinkler in a line of pipe after the first one is opened.

The opening temperature of the sprinkler is tested by means of a water bath. A double pail of water is suspended within the oven, so that the soldered joint of the sprinkler will be in about the middle of the inner pail, and thermometers are inserted with their bulbs as near to the soldered joint as practicable. The water is slowly warmed by a gas flame until a temperature of about 145° is reached, when it is kept stationary for a while, and then increased at a rate of not more than 1° a minute until the sprinkler opens.

In this manner the temperature of the opening of the sprinkler under any desired pressure is very accurately measured, and the whole process can be clearly observed, as the glass sides of the lantern prevent the hot water from being thrown about when the sprinkler opens.

The same apparatus, with the exception of the water bath, is used to test the positiveness of the operation of sprinklers, not merely of those which have been corroded, but also such sprinklers as are liable to be fixed in the act of opening by the water issuing from the opening sprinkler and striking and cooling the soldered joint before the parts are free. This is a defect to which quite a number of sprinklers are liable at time of trial, but it is doubtful whether sprinklers will be found in that position after an actual fire, as the amount of issuing water would not be sufficient to quench the fire, and, on the other hand, the fire would naturally extend until it produced sufficient heat to warm the water in the pipes to the melting point of the solder, and in that manner boil open the sprinkler.

One sprinkler would open as fast as any other using the same solder, if the heat rose slowly enough ; and, on the other hand, the ratio of speed of operation of sprinklers to each other is dependent upon the rate at which the temperature increases.

In regard to the sensitive tests of sprinklers, any measurement must be confessedly an artificial one, and so must the standard be as far as the method used is capable of exact reproduction. I have made a great many trials, both with gas flames and with solid fuel, but without obtaining satisfactory results. With gas flames, even when controlled by regulators, the calorific power of the gas would vary from day to day, and under the same conditions of pressure the gas, from different causes, would never be uniform. Even the burning of measured amounts of alcohol or similar fuel did not give exact results, as the increment of temperature would be quite variable, because with the amount of alcohol used under a slow sprinkler the temperature of the burning mass would increase to such an extent as very materially to add to the rate of heating ; and, therefore, the conditions of a slow sprinkler were not those of a sensitive one. At one time I tried to measure the sensitiveness of sprinklers by kindling fires from a measured amount of excelsior, in a building erected for the purpose, but the results were exceedingly unsatisfactory, varying in the time of operation from a ratio of two to one in consecutive experiments.

I finally used steam as the best means of obtaining a uniform increment of heat. The apparatus consisted of a large table, in the middle of which projected an open Parmalee automatic sprinkler, which is in form a reaction turbine, and was used for this purpose because it would throw the steam out radially over the surface of the table. This Parmalee sprinkler was

connected with a large section of pipe underneath, which contained some water in the lower part of it. Steam was blown into the lower part directly against the water, when necessary, in order that the reservoir should be filled with steam free from superheating, and controlled by a valve to the pressure of 15 pounds. The sprinklers were placed above this table, each containing a small quantity of water, and by means of rods and weights subjected to an opening force equal to 15 pounds per square inch. An electrical apparatus is so attached that when a sprinkler opened, a bell corresponding to that sprinkler would ring in an adjoining room, and thus notify the assistant who was making a record of the time by means of a stop-watch.

When a test was to be made a box of 30 cubic feet capacity was lowered face downward upon this table, and the valve lowered very slowly until the temperature of the box was raised to 100° F., this being the temperature to which sprinklers are liable to be exposed continuously in the extremes of summer and winter weather. Then the steam valve would be opened so that a pressure of 15 pounds would be admitted to the steam drum, and from thence through the sprinkler into the box.

The results of this method were very satisfactory, for the variation in the time of opening the sprinklers in the same lot was not over one-fifteenth of the time required for their operation. The time required by automatic sprinklers of different makes, but all using solder of substantially the same fusion point, varied from 12 to 95 seconds. Under these conditions the various types of sensitive sprinklers opened in from 15 to 21 seconds, the earlier types of sealed sprinklers requiring varying amounts of time up to the 95 seconds referred to above.

Although automatic sprinklers have proved to be so reliable and effective, yet, in order to provide for all possible contingencies, their introduction should not displace other forms of fire apparatus, particularly standpipes in the stairway towers with hydrants at each story. The hose at these hydrants should be festooned on a row of pins, or doubled on some of the reels made especially for such purposes. Standpipes are not recommended to be placed in rooms or on fire-escapes; and inside hydrants should not be attached to the vertical pipes supplying automatic sprinklers.

One pound of burning wood produces sufficient heat to evaporate six and one-half pounds of water, and, owing to the waste, a much larger proportion of water to fuel is necessary to quench a fire.

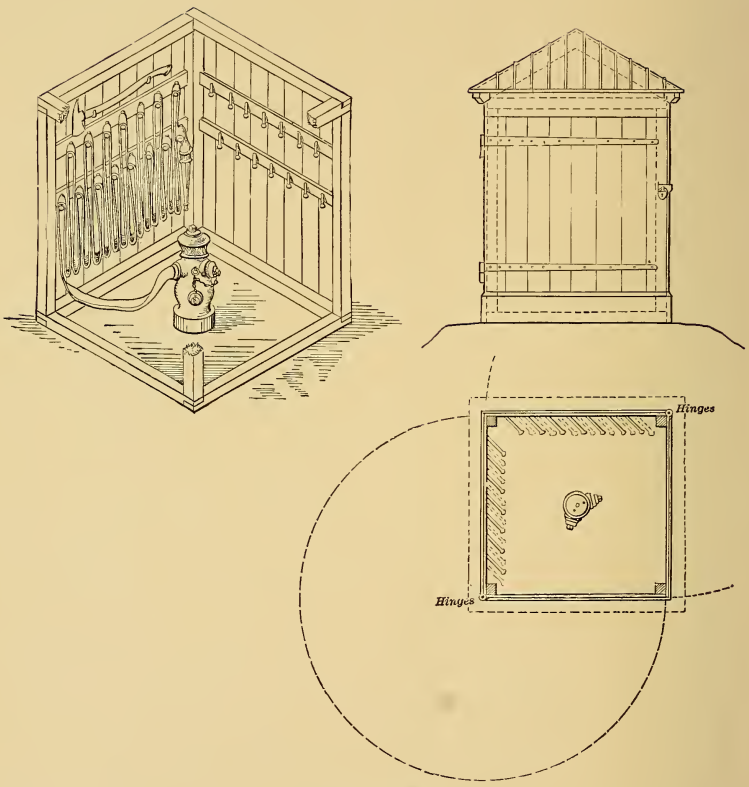
Fire-pumps are generally too small for the work required of them, five hundred gallons per minute being the minimum capacity recommended. For a five-story mill there should be an allowance of two hundred and fifty gallons per minute for an effective fire stream through a 1⅛-inch nozzle, and for lower buildings the estimate should rarely be less than two hundred gallons for each stream.

Contrary to the general assumption a ring nozzle is not so efficient as a smooth nozzle, the relative amount of discharge of ring and smooth nozzles of the same diameter being as three is to four. For standpipes ⅞-inch nozzles are recommended, but for yard hydrant service the diameter should never be less than 1-inch, and 1⅛-inch generally fulfills the conditions of best service.

It is important that the couplings on the hose and hydrants should fit those of the public fire department. The best diameter of hose is 2½ inches; the loss by friction under equal deliveries of water being only one-third in a 2½-inch hose of what it is in a hose 2 inches in diameter.

Fire-pumps should be equipped with a relief-valve and also a pressure-gage, and placed where they will be accessible under all circumstances, and so connected that they can be started at least once a week. The best location for fire-pumps is a matter differing with the conditions of each mill, but they should be situated as near to the source of supply as practicable, with full-size suction-pipe, easy of inspection and not containing any avoidable bends.

In a steam mill it is sometimes preferable to draft the water from a point below where the water of condensation is discharged into the stream, as there is less freezing there; in mills driven by water-wheels it is a convenience in time



HYDRANT HOUSE.

of repairs for steam fire-pumps to draft water from the wheel-pit. Rotary fire-pumps should have a short draft, but not placed below the level of the supply.

Water mains about a mill-yard should be of capacity not to cause an excessive loss by friction, their diameter being based upon a limit of velocity of 10 feet per second for the maximum delivery.

The yard hydrants should be placed at a distance of fifty feet from buildings, and covered with a house which should also contain hose, nozzles, axes, bars, and spanners. Hydrant houses are made in a great variety of forms, but it is important that the doors should be high enough to avoid ice, or that the house should be placed upon slight mounds. An economical hydrant house may be built six feet square with two adjacent sides hung on hinges, so that the doors can be swung around to the other side and be held by catches. The pins on which hose is hung should be two inches in diameter, and placed diagonally and staggered in two rows. If there is no hose cart, the reserve hose can be placed on shelves.

Stop-valves in the mains should be covered by boxes four feet in height, and the direction of opening clearly marked on the hand-wheel of the gate.

These methods of supervision, building, and equipment do not refer to any ideality, but to measures which have been widely carried into effect for the purpose of reducing the fire loss; the result of such action being to diminish the cost of insuring industrial property engaged in such normally hazardous processes as textile manufacture and other industries, down to a yearly cost of less than one-fourth of one per cent. This has been accomplished by the consideration of sources of danger and their abatement, and by a course which has been in line with sound engineering principles, and also practical methods of manufacture; and it has thus been proved that it is cheaper to prevent a fire than to sustain a loss.

There has been no attempt made to credit individuals with their share in these features of mill development. They have been the outgrowth of a continual profiting by experience, adopting some features and modifying others. The concurrent action of the large number of minds engaged on the same problem has led to duplication of methods; but the whole progress has been a matter of slow, steady growth, advancing by hairs' breadths, as the result of persistent efforts to adapt means to ends in the endeavor to reduce the cost of man ufacture.

WATER RAMS IN STEAM PIPES.

By Charles E. Emery, Ph. D.

THE bursting of a steam pipe in the U. S. S. *Concord* has brought out considerable discussion as to the cause of the accident. The writer of this article says, in the *Journal of the American Society of Naval Engineers*, that the principal cause of accidents in the operation of large, long steam pipes arises from the presence of water.

If steam be admitted at the top of a vessel partially filled with cold water, condensation will take place until the surface is somewhat heated, and this, in connection with a cloud which forms above the surface, will retard rapid condensation, so that in due time the full steam pressure can be maintained above water cold at the bottom. This phenomenon is not an infrequent occurrence in boilers in which the circulation is defective. It is therefore perfectly safe to heat up any vessel containing cold water, if the steam can be admitted from the top upon the surface of the water and so maintained. If, however, steam be blown in below the surface of the

water, a bubble will be formed, which will increase in size until its surface becomes sufficiently extended to condense the steam more rapidly than it can enter, when a partial vacuum will be created, the bubble will collapse, and the water flowing in from all sides at high velocity will meet with a blow forming what is called a water ram. In blowing into a large vessel these explosions occur in the middle of the mass, and create simply a series of sharp noises. If, however, steam be blown into a large inclined pipe full of water, it will rise by difference of gravity to the top of the pipe, forming a bubble, as previously stated; and, when condensation takes place, the water below the bubble will rush up to fill the vacuum. giving a blow directly against the side of the pipe. As the water still further recedes the bubble will get larger, and move farther and farther up the pipe, the blow each time increasing in intensity, for the reason that the steam has passed a larger mass of water, which is forced forward by the incoming steam to fill the vacuum.

The maximum effect generally takes place at a "dead end," as it is called, or where the end of the pipe is closed. Even if the water does not originally extend to the "dead end," if the pipe near it be once filled with steam which has bubbled through water on its way to that point, there may be sufficient cold metal to condense it, so that the collapse will take place on the same principle as before, and the whole mass of water in the pipe be driven by the incoming current of steam against the end, sometimes with tremendous force, the effect being to cause leaks, and sometimes rupture the pipe or break out the end connections. It is not necessary, either, that the end of the pipe be closed. In fact, under certain conditions, a more forcible blow is struck when the end of the pipe is open, as, for instance, when a pipe crowned upward is filled with water, one end being open and the steam introduced at the other. A bubble will in due time be formed at the top of the crown, when the water will be forced in by atmospheric pressure from one end and by steam pressure from the other, and the meeting of the two columns frequently ruptures the pipe. Evidently, too, the same action can occur without difficulty in a level pipe, but, as previously stated, cannot in a pipe which descends away from the entering steam, so that the latter is *always* above the water.

It is evident from the above that it is always desirable in turning steam on an inclined plane to introduce it from the top, and let the water out of the bottom of the slope. When this can be done, any workman can be trusted to attend to it. Frequently, however, there are undulations in the pipe, and at times mains which may contain water have to be heated by letting the steam in at the lower end, and letting the water out before the steam is admitted. The same thing can be done with underground pipes, and provisions for this should always form a part of the plans when it is known that a pipe will have to be heated up in this way.

In practice, however, a street system contains so many absolutely necessary details that a provision of this kind will not be originally provided for, and at times it will occur that a main which it was expected to heat from the top of the slope, may, from something being out of order, necessarily be heated from the other direction. Difficulties also occur in small pipes where the extra labor and expense required to provide special drains for overcoming this difficulty would not be warranted, particularly as another solution of the difficulty is available, even with pipes of considerable size.

If a blow-off opening be provided at one end of a main to be filled with steam, even if such blow-off be at the higher end, any water in the main can be driven out of the blow-pipe, provided the steam valve be opened sufficiently wide to keep the pressure continuously maintained against the water. The explanation of this is that if the steam supply be limited the water will run back under portions of the steam, forming bubbles which may suddenly collapse and produce water rams; but if the steam supply be practically unlimited, or at

least sufficient, the steam will force the column of water back along the bottom of the pipe, as any vacuum formed will be filled by the steam driving back the water. There will be a series of small explosions, which will scarcely be heard and do no harm, and the seething wall of water will be continually forced forward and finally out of the pipe.

Note the distinction in the two methods of operation necessary to suit the conditions. When the steam is on the top of the water, it may be turned on as slowly as desired, and it is better to turn it on slowly, as thereby the heavy castings are heated slowly, and are not so liable to be strained. But when steam *must* be turned in the lower end of a descending pipe which *may* be filled with water, the valve must be opened sufficiently to establish a definite current and keep up the pressure. This will not require the valve to be wide open, but the result will be substantially as though it were open. Practical engineers, who on sea and land have had to do with turning on steam in pipes, naturally recoil from turning steam quickly into any pipe, and it is very hard to explain to them the difference. I have had to take a party of men of this kind, state the reasons for action, and in one case I recollect using as an illustration, that if a farmer with a pitchfork could get an officer on the run, the latter could not draw his sword, turn, and defend himself, as he would be run through before he came to close quarters. The principle applies to the water in an ascending pipe. The column of water once started, the steam, if the supply be made sufficient, follows it up so closely and in such volume that no condensation can take place sufficiently to stop the onward movement.

The clearing of a pipe in this way requires nerve and judgment, but I have seen considerable cold water driven up hill out of a six-inch pipe 1400 feet long with a difference of elevation at the two ends of fully twenty feet, by letting steam in at the lower end and blowing the water out on the street through a two-inch blow-off pipe. The blow-off pipes are made no larger than this, even for mains fifteen and sixteen inches in diameter, but I do not consider that it would be safe to attempt to clear an ascending main of this size with this size of blow-off pipe. All these mains are more nearly level, have blow-offs at low points, near the valves, and can be blown off by putting steam in at or near the summit. In heating up an eleven-inch pipe, only 400 or 500 feet long, from the bottom, I have had the flange taken off the extreme end in order to give the water free exit and prevent the possibility of a ram.

THE RELATIVE TEST OF NEW AND OLD METAL.

THE fatigue of metals under continuous strain has long been a subject of discussion. The *Electrician*, of London, in a recent report on the subject, says, "A square iron link 12 inches wide, 1 inch thick, and about 12 feet long, was taken from a bridge at Kieff, then about forty years old, and tested against a similar link which had lain unused in store ever since the building of the bridge. The means of comparison was, therefore, excellent, and the result should go a long way to show whether or not iron does lose any of its strength in prolonged service. The effect of the tests was to determine for the old used link an ultimate tensile strength of 21.8 tons per square inch, an elastic limit of 11.1 tons per square inch, an elongation of 14.05 per cent., and a contraction of 17.35 per cent. at the point of fracture. For the unused link the tensile strength was found to be 22.2 tons per square inch, with an elastic limit of 11.9 tons, and elongation and contraction at fracture of 18.42 per cent. and 18.75 per cent. respectively. The two pieces of iron were, therefore, of practically identical strength; for the small difference actually observed is well within the ordinary range of variability of similar pieces of the same metal."

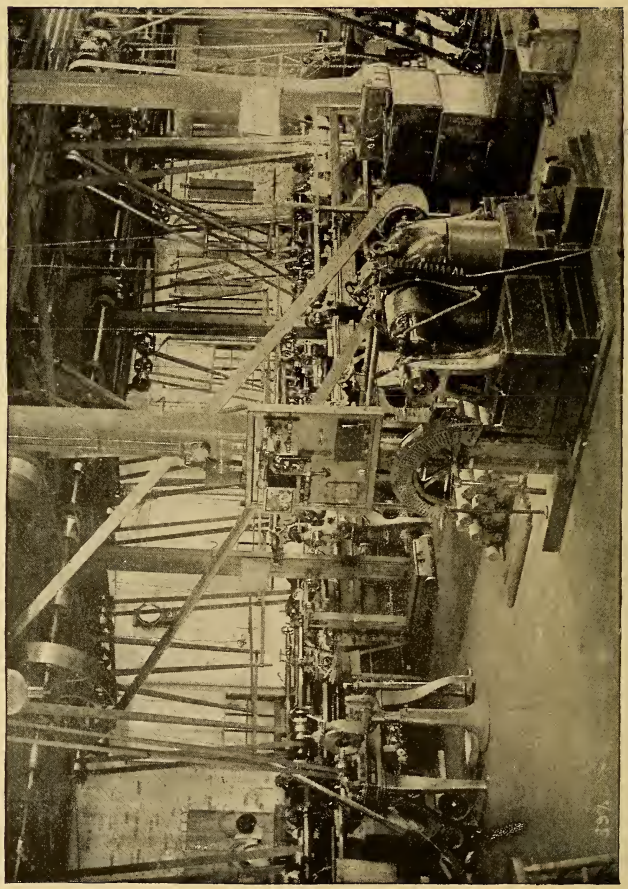


FIG. 29.—ELECTRIC MOTOR OPERATING MACHINE SHOP.

ELECTRIC-POWER DISTRIBUTION.*

By H. C. Spaulding.



AT a recent meeting of the American Society of Mechanical Engineers a very lively discussion was brought out by a paper treating not of what electricity had done, but what it might do, in the line of passenger transportation, and the remarks of a number of members who took part in this discussion showed a deep interest in the development of electrical appliances as adapted to manufacturing processes.

The commercial possibility of transmitting power for comparatively long distances by electrical means, when the losses attendant upon such transmission by any other system would be prohibitory, is sufficiently well known and acknowledged at the present time to call for no extended comment. Curiously enough, our friends on the other side of the Atlantic are far in advance of us in the utilization of natural energy for lighting and power service, although the number of water-power installations is rapidly increasing in our Western States and Territories, where the high cost of fuel would naturally bring about such a result. In Switzerland alone there are already upward of two hundred electric-power stations utilizing water power for operating lights and motors over extended areas, while possibly the best-known illustrations of such service in our own country are at Spokane Falls and Aspen.

It is the purpose of this article, however, to separate, so far as possible, the closely allied topics of power transmission and power distribution, electrically considered, and to treat the latter principally in the light of its adaptability to manufacturing and constructing operations. It is accordingly immaterial, so far as the scope of this article is concerned, whether we are to utilize a water privilege ten or fifteen miles away, and possibly so situated between high and precipitous banks as to render it impossible to locate our manufacturing plant there, or to distribute the power furnished by a steam plant in the immediate vicinity, which may, however, be so isolated as to reduce fire risks to a minimum while taking advantage of the most economical situation for coal and water supply. Let us assume, therefore, that we are provided with an electric-current supply sufficient in quantity to operate whatever apparatus we may wish to connect, and of sufficiently low pressure or "voltage" to allay any fears of personal injury on the part of employees.

The "main shafting" naturally demands our first attention, and if the buildings are of more than one story, the advisability of dividing the plant into sections, each one of which may be started and stopped independently of any other, and without belt towers or belt holes (those efficient dust and fire conveyers), is evident to the most superficial observer; while in a single-story building such subdivision reduces to a minimum the friction of lines of shafting, run most of the time, it may be, for the operation of only two or three machines. Engineers will appreciate fully the tales the indicator will tell, in nine out of ten of our large manufacturing plants, of the power devoted to revolving the immense "main shaft" and in transmitting power from one line of shafting to another when not a single machine tool is in operation. While it is not advisable to run any but the largest tools by separate motors, it will usually be found possible to group machines in systems requiring from 10 H.P. upward, and so arranged that the average of power required will not vary between wide limits, and such variation will not occur suddenly. We can then connect with the shafting for each group a properly designed motor, which may be started and stopped almost instantaneously, and, if desired, allowing of delicate adjustment of speed.

Fig. 29 shows such a motor operating various classes of apparatus and placed on the floor precisely as a small engine

*Paper read before the American Society Mechanical Engineers.

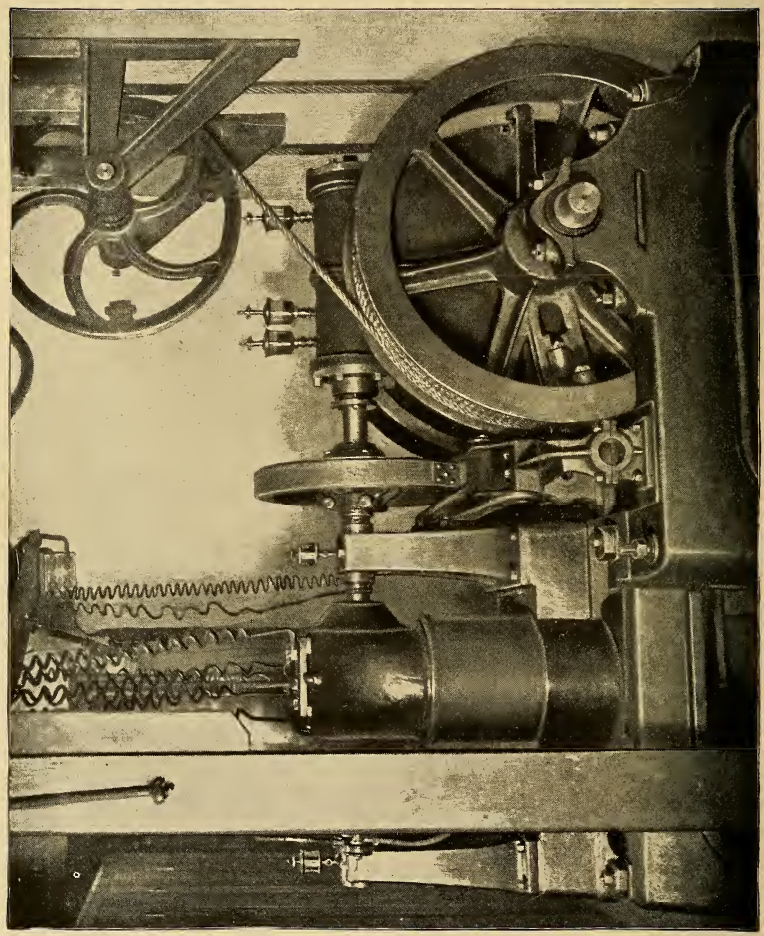


FIG. 36.—ELECTRIC PASSENGER ELEVATOR.

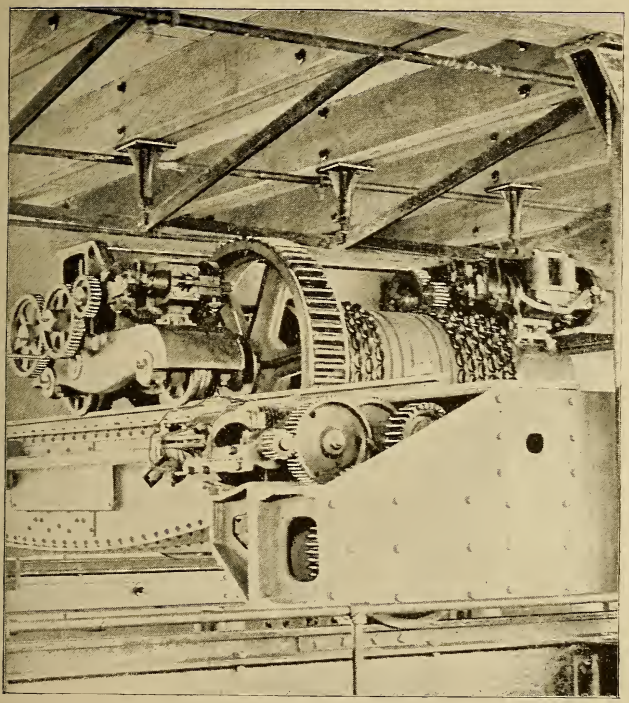


FIG. 31.—ELECTRIC TRAVELING CRANE BUILT BY THE MORGAN ENGINEERING CO., ALLIANCE, O.

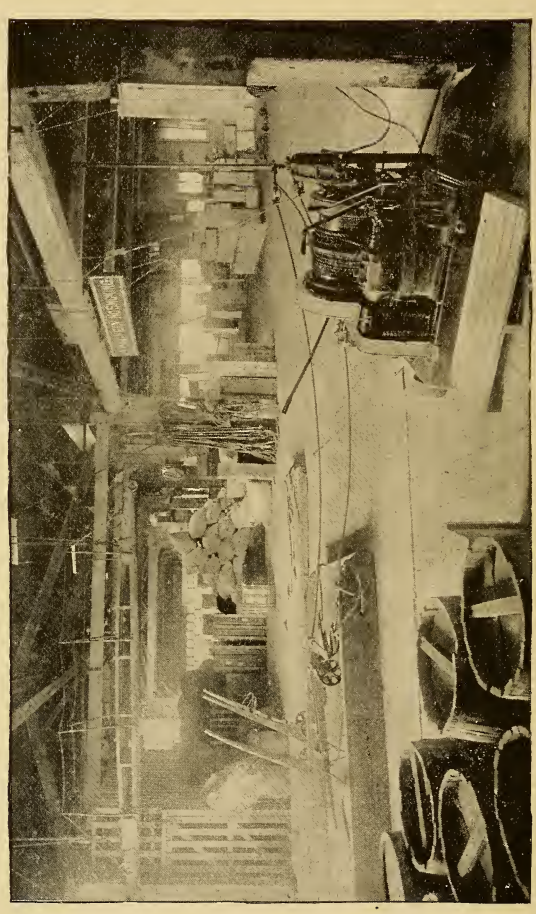


FIG. 34. - PORTABLE ELECTRIC HOIST.

would be, but requiring no special foundations (owing to the absence of reciprocating motion and consequent pound), and belted to the shafting in the ordinary way; while Fig. 30 shows a motor of 15 H.P. capacity, connected directly to the shafting, with the controlling apparatus placed within easy reach of the floor on wall or post, as may be most convenient. When the shafting is more than ten or twelve feet from the floor it will usually be found advisable to provide a light platform on which to stand when inspecting or oiling.

The motor shown in Fig. 30 operates two Pond planers of 84 inches and 72 inches respectively, one 5-foot Warren radial drill, also a large double grinder; and is one of a system comprising more than twenty separate motors operating at distances varying from 200 to 1400 feet from the central engine and generator. Another motor in the same factory and of the same size (15 H.P.) operates two 36-inch planers, two 32-inch planers, six 32-inch lathes, one 42-inch lathe, one 48-inch chucking machine, four 5-foot Prentice radial drills, and a large double grinder.

The application of motors to the operation of one or two machines by means of countershafting is of course a small matter, and calls for no special comment.

The increase during the past few years in the size of construction parts and machine tools has called for a corresponding increase in the power of devices for handling them, as demonstrated by the number of traveling cranes put in by the larger manufacturing plants. The friction losses in transmission by square shafts or other prevailing methods are excessive, and the possibility of operating the heaviest traveling cranes without mechanical connection between the crane trolley and the source of power, as provided by electrical means, appeals at once to the engineer, providing the losses in transforming from mechanical to electrical energy and back again are not excessive. Fig 31 shows such a crane of thirty tons' capacity and some of its construction details. The following data concerning this piece of apparatus, which was built by the Morgan Engineering Company, and equipped with Thomson-Houston motors, may be of interest.

Three motors are used, one of 3 H.P. capacity for cross travel, and two of 10 H.P. capacity for hoisting and longitudinal travel respectively. The three movements may be obtained in any combination of direction and speed, as each motor is provided with a separate controller. The motors are built for 220 volts, and receive the current from two trolley wires running one on either side of the main floor, resting on insulators, a copper brush attached to either end of the bridge lifting the wire as it passes along, somewhat as in the method employed by cable cars in lifting their cables. The motors on the crane trolley receive their current through carbon brushes sliding along copper strips placed on the inside of the bridge. The total longitudinal travel of the crane is 165 feet; length of bridge between rails, 27 feet 2 inches. Total lifting space, 21½ feet. A "solenoid" brake is provided, which holds the hoisting gear automatically and instantaneously whenever the supply of current is shut off from the hoisting motor.

The extreme ease of operation, and the fact that the expenditure of power is almost exactly proportional to the work accomplished, and ceases absolutely when the crane is not in motion, are important features of this class of apparatus.

A simple and ingenious application of electro-magnetic principles is illustrated in Fig. 32, a load of almost five tons being held suspended by the attractive force of a magnet weighing only one-tenth of that amount. Such a device may often be used to great advantage in handling pig-iron, castings, boiler plates, etc., owing to the speed with which the operation of "picking up" and "letting go" may be accomplished. A simple "make and break" switch answers for a controlling device, and may be located either on the magnet itself, or at any desired point. By a simple device, the quantity of current, and proportional strength of the magnet, may be varied at will by the operator, so that in handling small pieces, such as bolts, rivets, fittings, etc., only the desired amount may be lifted.

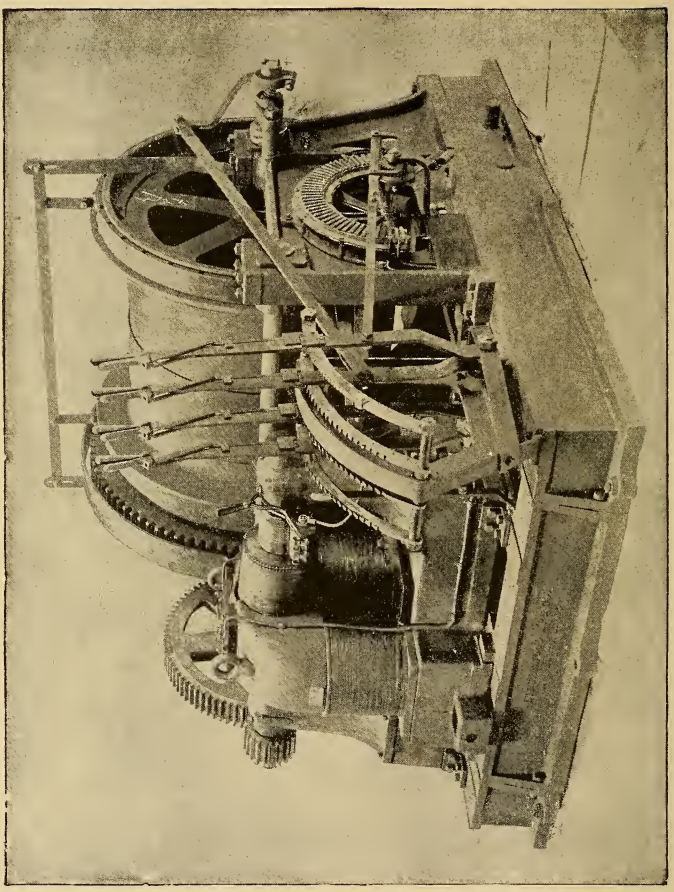


FIG. 35.—ELECTRIC HOIST, 35 H.P. CAPACITY.

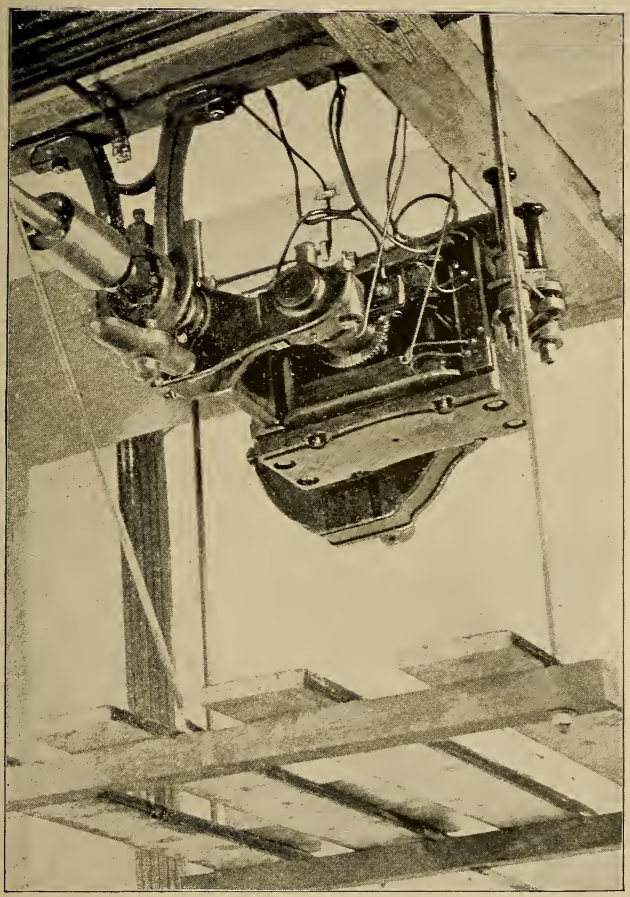


FIG. 30. – ELECTRIC MOTOR COUPLED TO SHAFTING IN MACHINE SHOP.

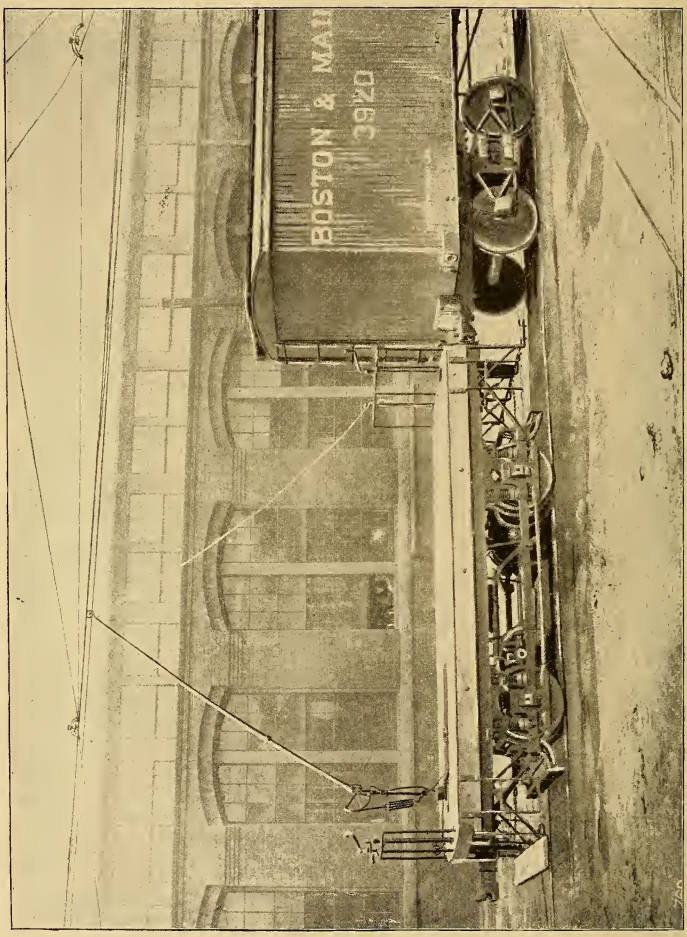


FIG. 38.—ELECTRIC MOTOR FOR SHIFTING FREIGHT.

One of the most useful applications of electric motors is in connection with hoisting apparatus of various kinds, including passenger and freight elevators. A power hoist is often required in a storehouse or shipping room at some distance from line shafting, which it would be expensive to extend, while steam-piping means possible injury to stock from frozen or leaky pipes, and a small steam plant means increased insurance. Under these circumstances the electric hoist is available, taking its power from a pair of wires which may be carried over and through buildings and around corners with a minimum of space, care, and expense, and a maximum of convenience, economy, and safety. A portable hoist of 15 H.P. capacity, designed especially for dock work, is shown in Fig. 33; one of the same general type, but fitted with a double rope, being shown in Fig. 34, unloading a steamer's cargo. These hoists are furnished with a few feet of flexible cable, and may be connected in a few seconds with "service plugs" located on various parts of the wharf, the current being taken either from the lighting wires on steamer or shore, or, better, from a special power circuit, if such be available. Hoists of this kind may be advantageously used for building operations, and are appreciated on account of the absence of smoke and noise.

Fig. 35 shows another hoist of the same general type, but of 35 H.P. capacity, and designed for heavy work.

The earlier applications of electricity to elevator service were not specially successful, except for slow speeds, as it was not for some time considered feasible to start, stop, and reverse the motor itself, thus imposing the disadvantages inherent in "open and crossed belt" machines upon all electric elevator installations.

The only practical method of using motors for high-speed passenger work was for some time, therefore, in operating the pumps of hydraulic systems, but of late the development of quick-controlling and reversing apparatus, with special types of motors, has made possible results fully equal in smoothness of operation to the best hydraulic practice, while the running expense is usually considerably less. Designs are in use for a double-drum freight or slow passenger type of machine, in which the movements of the apparatus are controlled entirely by electric means, the armature shaft of the motor being run in either direction at will, and at any desired speed.

Fig. 36 represents an improved high-speed passenger machine now in operation in a large business block in Boston, the controlling mechanism being entirely in the car and operating through flexible cables. Automatic brakes are provided, which are thrown into operation by the shutting off of the current, while the usual safety devices against over-travel and breakage are present, with others of a purely electrical nature.

The enormous areas required by many of our industrial concerns for carrying on the various processes of manufacture to the best advantage necessitate new and improved methods for the transportation of fuel, supplies, and material in various stages of treatment from one part of the plant to another; and here again the invisible agent electricity offers its services in a safe, compact, and effective form.

While the economy of electric locomotive-truck service is naturally dependent upon local conditions and the amount of material to be carried, the saving over other methods has been entirely satisfactory to the score or more of corporations which have adopted it up to the present time. Fig. 37 shows an electric truck as applied to various lines of millwork, the motors being of 3 H.P. capacity, and using the regular lighting current, while a larger size is shown in Fig. 38, suitable not only for general yard trucking, but having sufficient power to act as a yard shifter for freight cars, being fully equipped with extra heavy brakes, draw-bars, and buffers for this purpose.

Among the numerous auxiliary uses to which electric apparatus may be put is that of pumping, either for boiler feed or general supply purposes. A number of automatic switches are now on the market, by means of which an electric pump may be automatically started or stopped by a change of water-level either

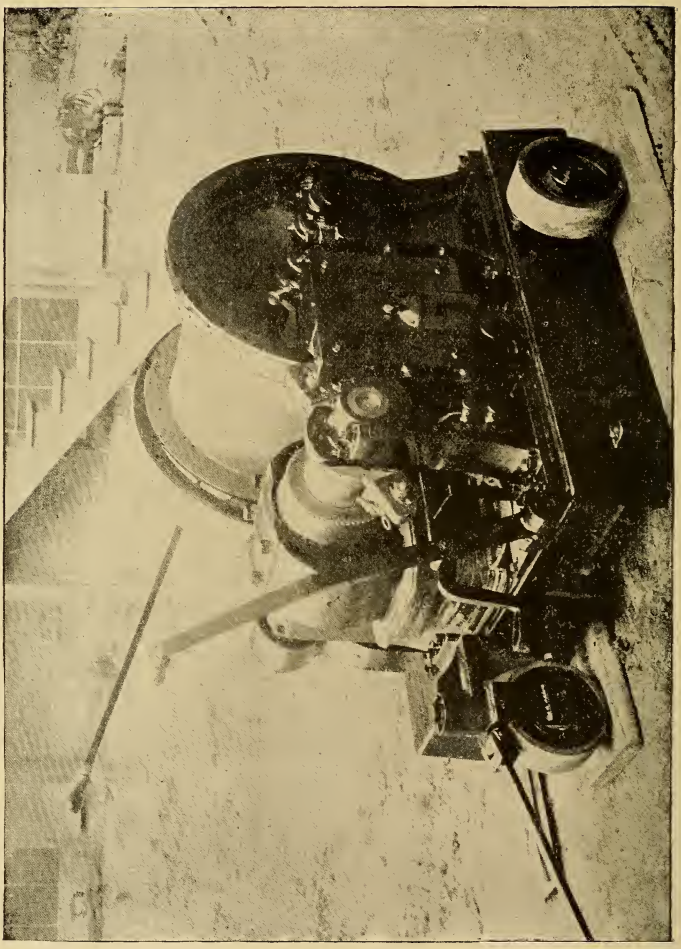


FIG. 33.—PORTABLE ELECTRIC HOIST, 15 H.P. CAPACITY.

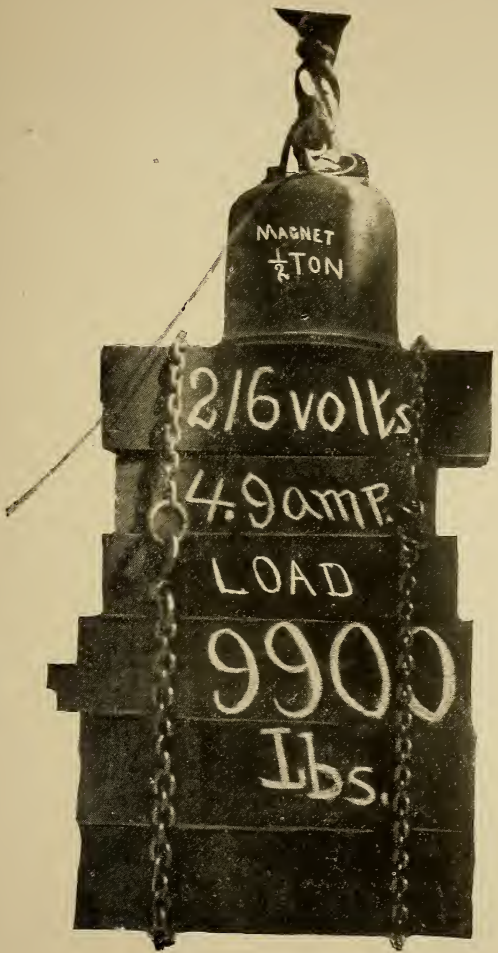


FIG. 32.—ELECTRO-MAGNETIC HOIST.

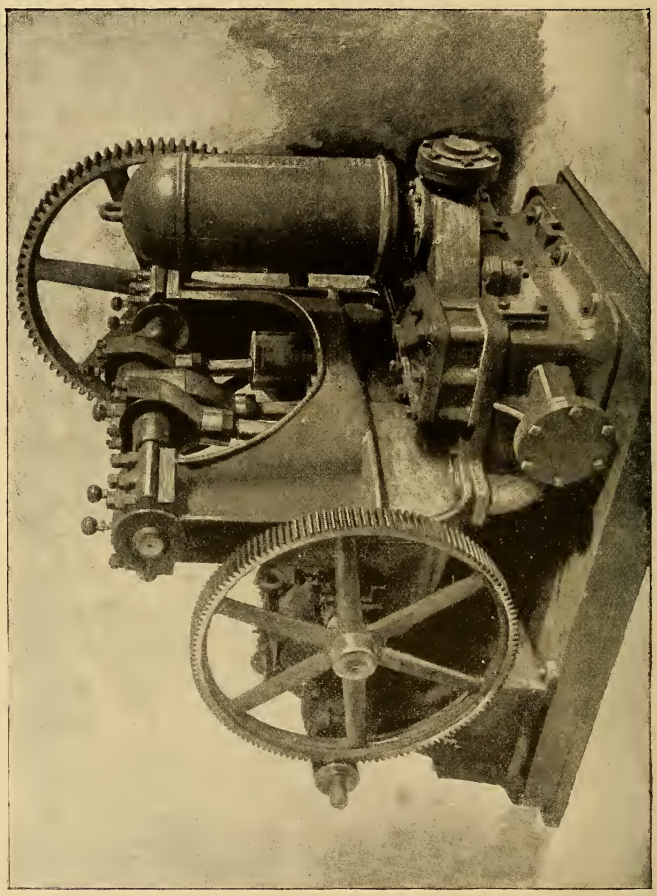


FIG. 39.—ELECTRIC PUMP.

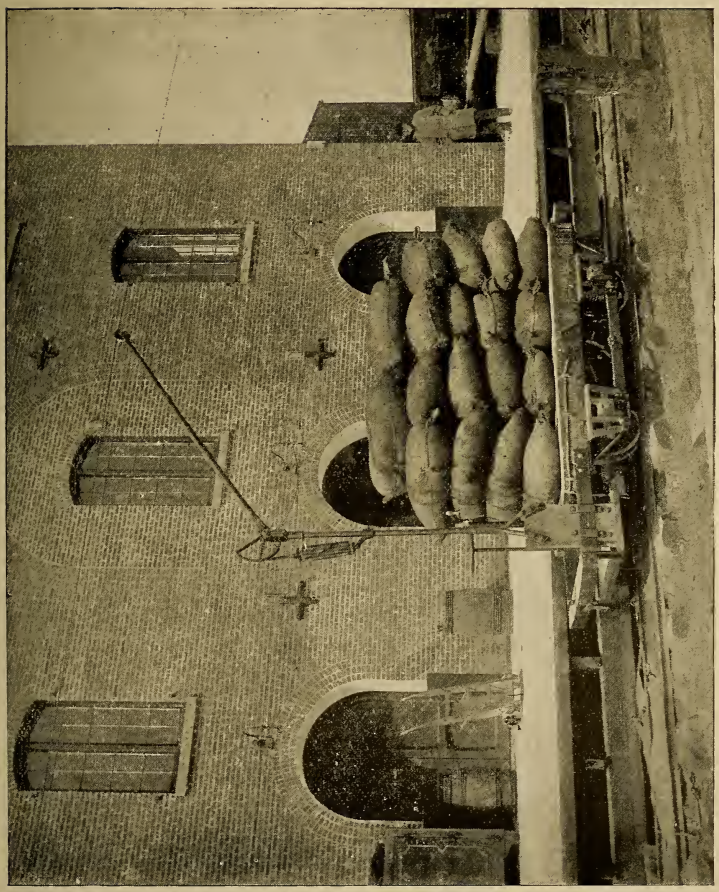


FIG. 37.—ELECTRIC TRUCK FOR MILLWORK.

in a gravity or pressure tank, a feature susceptible of numerous adaptations as suggested by circumstances.

Fig. 39 shows a form of pump specially adapted to general supply purposes, which is made in sizes of from 10 to 500 gallons per minute capacity.

An objection sometimes offered to the adoption of electric apparatus is, that owing to the "youth of the art" the types of machines now built and on the market will in a few years be obsolete, like a coat outgrown but not outworn, so that the necessary investment is an unwise one on the part of the purchaser. This view seems to the writer not fully warranted, in the light of recent developments in electro-dynamics, since the efficiency of this class of machinery is now so high as to direct the ingenuity of electric engineers rather to the invention and improvement of auxiliary apparatus for controlling, measuring, and protecting the currents produced, than to the invention of new apparatus for their production.

The claim may now fairly be made also that the various "gages" of the electric systems have been brought to standard, and that a piece of apparatus bought of any reliable company is adapted for use as well in conjunction with apparatus produced by another, and it may be competing, concern, provided the two systems are of the same general nature. This is just as necessary as that there should be one standard of measurement for engineering supplies of any kind, arbitrary, to be sure, but binding by courtesy throughout the engineering fraternity.

In conclusion, it is interesting to note the tendency to incorporate electric motors with various classes of machinery, thus forming complete mechanical units. It is to-day possible, for example, to equip a printing or publishing house equal in completeness to any now existing, without using a hanger, line shaft, or belt, each press being complete in itself as far as mechanical connection with the source of power is concerned, the entire transmission being accomplished by means of concealed wires.

The same is true of almost every line of industry, while the general application to naval practice is apparently a matter of the immediate future.

THE LONGEST STEEL OR IRON SHAVING.

THE time-honored controversy over the question, Who has seen the largest sea serpent? is likely to give place to a query of different character, viz: Who has seen the longest iron or seel shaving? In a recent issue *The Iron Trade Review* referred to the fact that Wm. E. Donnelly, a Cleveland machinist, claimed the longest iron shaving, which is 107 feet, whereupon Geo. Berschig, another Cleveland machinist, produced an iron shaving 111 feet long. This brought out the fact that there is on exhibition at Worth's museum, New York, an iron shaving 175 feet. This has heretofore been claimed to be the longest in the world, but Charles Chaffey, still another Cleveland machinist, came forward with the statement that he saw an apprentice in the works of the Brush Electric Company, in Cleveland, turn off an iron shaving 237 feet in length. The honor did not long rest on the brow of the Brush Company's apprentice, for in the St. Louis *Stoves and Hardware Reporter*, of October 15, appeared an article which showed that the longest steel shaving yet produced, of which there is a record, is one 255 feet long, now on exhibition at the Homestead Steel Works, Pittsburgh, Pa., where are made the great steel bolts to fasten plates to vessels. Another long steel shaving referred to in that article was the one produced, some years ago, at Woolwich Arsenal, England, having been turned off a gun and measuring 171 feet. It was on exhibition at the same time as one of the greatest curiosities extant. There is nothing now left but to wait for the next big shaving, or story, as the reader may prefer.

MECHANICAL REFRIGERATION.

By Edgar Penney, M.E.



THE idea of producing cold by mechanical means dates back many years, although the practical and successful accomplishment of the purpose is of quite recent date.

As early as 1824 an apparatus was constructed by which ice was to be produced, and at various intervals afterward different ideas were suggested, but it was not until 1855 that a machine which could be called successful was built.

mometric scale that the heat of the earth is sufficient to maintain them in the gaseous state, and at no time so low that they will be condensed and restored to their liquid state. It is simply necessary to call attention to the numerous experiments made by prominent physicists who have proved this theory, by subjecting all known gases to artificial cold and pressure and condensing them to a liquid. This is the method in common use for liquefying gases, that is, to subject them to constant pressure, and while in this state to rob them of their latent heat of vaporization, by allowing cold water to flow over the apparatus, or in

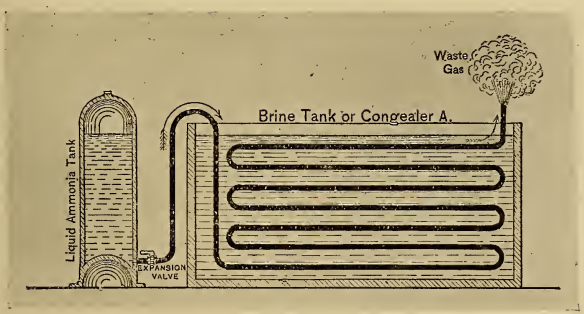
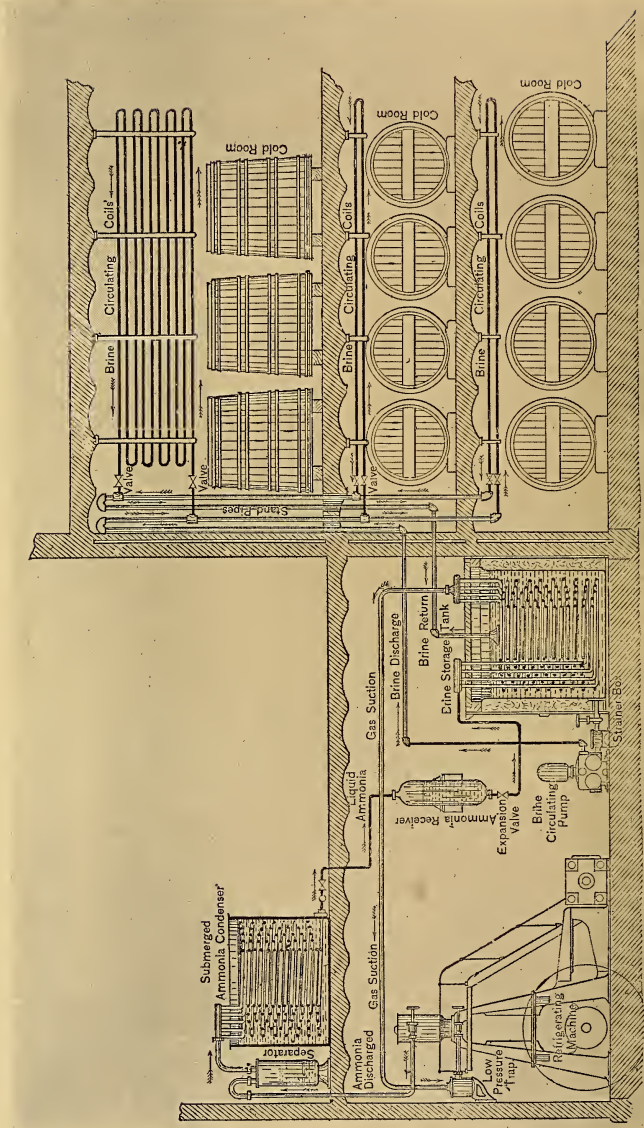


FIG. 1.—ELEMENTAL REFRIGERATING APPARATUS. TWO PARTS. SIMPLEST FORM OF REFRIGERATION MACHINE (ILLUSTRATIVE).

The theory of the artificial production of cold is based on natural laws which are well known. All liquids will vaporize or pass into a gaseous state at some temperature, while gas in passing off will carry away a definite amount of heat from objects by which it is surrounded.

All the so-called permanent gases, such as hydrogen, nitrogen, and others, including the compound air itself, are simply the vapors or combination of vapors or gases of some liquid whose boiling points are so low upon the thercase of the more permanent gases, at the same time subjecting them while in the condenser to the most intense artificial cold that can be produced and thus liquefying them.

Of course, the substance selected for refrigerating purpose must be one which will vaporize at a very low temperature, and although there are a number which will do so, such as ether, carbonic acid, nitrous oxide, sulphurous oxide, and ammonia, the latter is used almost entirely, for beside boiling or vaporizing at



COMPLETE REFRIGERATING PLANT WITH PIPES IN ROOMS. BRINE SYSTEM.

a temperature of 28½° below zero, it does not present any danger from inflammability or explosiveness as does ether and other material; nor has it any bad effect upon iron even when mixed with water.

It is well known that increasing the pressure upon a liquid raises its boiling point, and from this fact you can see that liquid ammonia, which will boil at 28½° under the pressure of one atmosphere, would have its boiling point raised in proportion to the pressure to which it is subjected, and you can readily see that this can be carried to such an extent that the boiling point of ammonia can be thus mechanically raised to any temperature

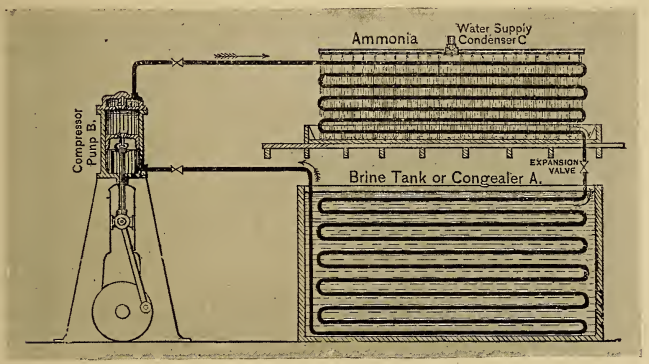


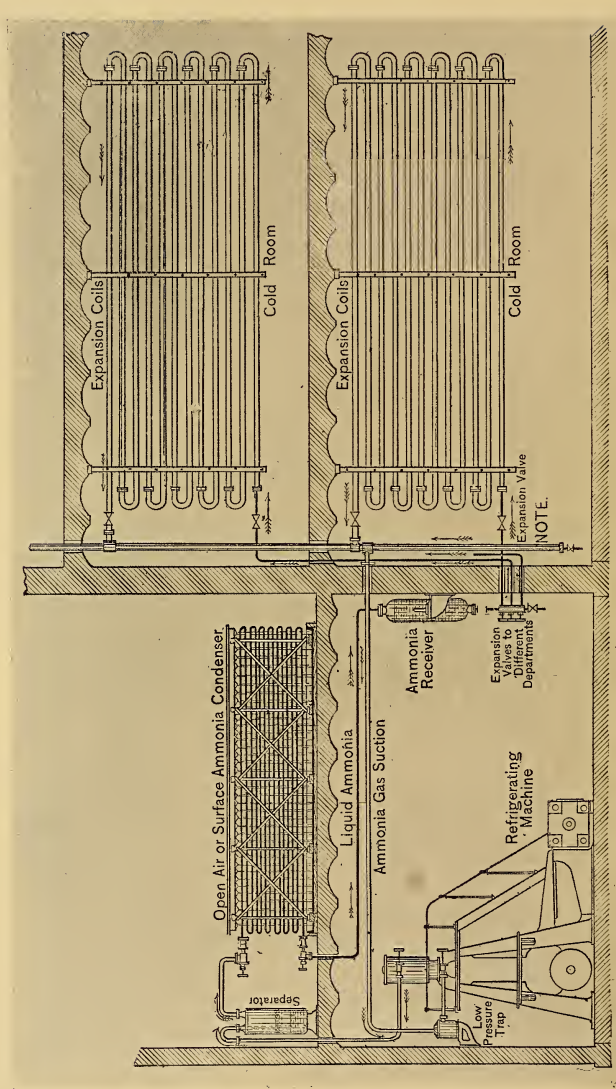
FIG. 2.—OUTLINE DRAWING OF MECHANICAL COMPRESSION SYSTEM.

desired. Gas at a given pressure must have a temperature or boiling point to correspond. As you know, the boiling point of water at 15 pounds absolute is 212°, and the temperature of its gas or steam is likewise 212°.

Pressure and temperature are interrelated. That is to say, at a certain pressure saturated gas has a corresponding temperature, and this is also the case with ammonia. Hence, if the gas, while subjected to a certain uniform pressure or artificial atmosphere, be discharged into an air-tight vessel which is being constantly cooled by water of a somewhat lower temperature than that due to the pressure of the gas, the vapor will necessarily under these conditions collapse and be condensed inside the vessel and go back to the liquid form.

The temperature of the water available for use on the condenser determines the pressure to which the gas must be subjected in order to raise its boiling point or artificial atmosphere high enough so it cannot exist as vapor, but will collapse when chilled by contact with condensing surfaces slightly colder than itself.

The colder the water is, the less pressure necessary, and for that reason in nearly all refrigerating plants the condensing water is taken from artesian wells, the temperature of which is generally quite low, and remains quite uniform both in summer and winter. The popular idea is that heat should be hot enough to burn. As a matter of fact the absolute or real zero of the negative scale is 461° below the zero of the thermometers, so that within this great range it is more a question of the relative difference of temperature between two bodies brought in contact that determines the amount of heat that is lost by the one and gained by the other, than the exact position in degrees they occupy upon the thermometric scale. The hottest will invariably impart its heat to the coldest until temperatures are equalized, and in the case of the ammonia whose boiling point is 28½° below our zero, it will continue to



COMPLETE REFRIGERATING PLANT WITH PIPE-COILS IN POSITION. DIRECT EXPANSION SYSTEM.

NOTE.—Pipes here shown on the sides to better illustrate the System. In practice they are put on sides or ceiling, to suit the premises.

boil at atmospheric pressure and carry off heat so long as it is in contact with any substance hotter than itself, or above 28½° below zero, making that substance continually cooler by absorbing its heat, or at least until it has been reduced to a temperature corresponding to the pressure under which the ammonia gas is formed; this point reached, the ammonia will cease to evaporate and remains in a liquid state.

The real index of the amount of cooling work possible is the number of pounds of ammonia evaporated between the observed range of temperature.

To make the above clear, I will add

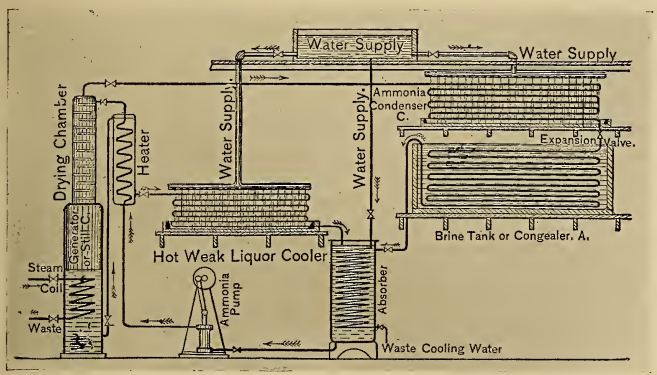


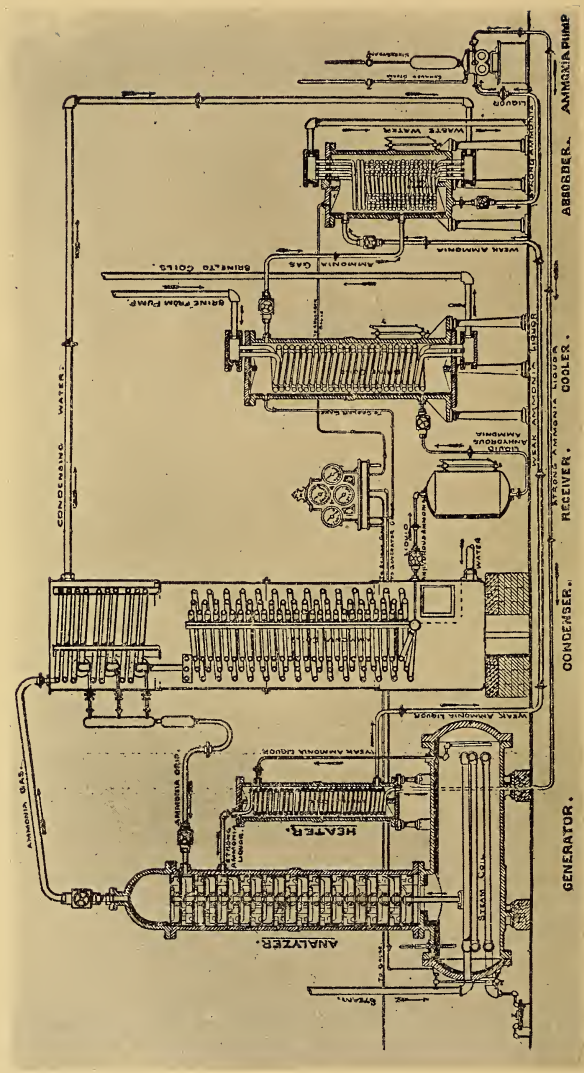
FIG. 3.—ABSORPTION REFRIGERATING APPARATUS. SEVEN PARTS.

that each pound of ammonia during evaporation is capable of storing up a certain quantity of heat, and that the simplest forms of refrigerating apparatus might consist, as shown in Fig. 1, of two parts, a congealer and a tank of ammonia. In this apparatus the ammonia is allowed to escape from the tank into the congealer as fast as the coils therein are capable of evaporating the liquid into a gas; when completely expanded, the resulting vapor is allowed to escape into the atmosphere, which means it is wasted, the supply being maintained by furnishing fresh tanks of ammonia as fast as contents are exhausted. This process, while simple, would be tremendously expensive, costing at the rate of about $250 per ton refrigerating or ice-melting capacity. To recover this gas and reconvert it to a liquid on the spot in a comparatively inexpensive manner, is the function of the compressor pumps and condensers of the refrigerating machine.

There resided in New Haven about 1848 Prof. Twining whom the world has forgotten, but who really produced the first successful refrigerating machine used in this country. Considering the fact that after operating for about two years this machine was abandoned, it perhaps should not properly be called successful, but as its construction embraced the principles of the successful apparatus of to-day a description of it may be of interest.

In his experiments, Prof. Twining discovered that in evaporating one pound of ether it would produce 1.2 pounds of ice, calculating from water at a temperature of 32°. After securing a patent on his machine, in England as well as America, he had an apparatus built, which was erected in Cleveland. In this machine he used a double-acting vacuum and compression pump 8½ inches diameter, with 18-inch stroke. It was run at a speed of 90 revolutions per minute.

The vapor from the ether was compressed with a condenser of the tubular



SECTIONAL VIEW OF A LEADING ABSORPTION SYSTEM.

type, where it was liquefied. After this it passed into a tank, to be re-evaporated by the sucking action of the pump. The tank was cooled to a temperature below the freezing point. This tank was arranged to hold a series of iron moulds open at the top, and these were surrounded by brine which itself would not freeze, but the water in the tanks was frozen into solid cakes, as is done to-day. While the temperature in freezing was not very low, Prof. Twining found that after the ice was formed it did get as low as 25 or 26 degrees below zero, but the ice made at this temperature was not clear. During the two years the machine was in operation (not continually) its daily production was from 1000 to 1500 pounds of ice. The principal reason this apparatus was eventually abandoned was because of the great danger owing to the inflammability of the ether and for the reason that air continually found its way into the apparatus owing to the high vaccum employed. There was also much difficulty found in obtaining proper lubrication. For some years after this machine ceased to be operated nothing new appeared. Ferdinand Carré, of France, sometime about 1860, originated a new method of liquefying ammonia. The general plan of operation in his original machine was similar to that of which an illustration is shown on page 158, and is known as an "absorption" system. There are a number of defects in the absorption system, among which may be mentioned the rapid deterioration of the coils and boiler-plate work in contact with aqua ammonia, which has a peculiar action under the condition of its use on these parts; failure to secure a dry gas from the still, notwithstanding the use of complicated drying chambers, the vapors passing from the generators being saturated with steam from the water, which, passing along with the gas into the condenser, is therein condensed, accumulates and reabsorbs the ammonia in large quantities, entailing a considerable loss of efficiency and waste of fuel.

A large amount of fuel is required to boil off the ammonia from the aqua solution. Comparing the work done in a still, liberating a given number of pounds of gas from the aqua into the condenser, with a mechanical compressor discharging the same quantity of pure anhydrous gas, the proportions are shown by calculations and confirmed by practice to be nearly as 1 to $1\frac{6}{10}$, that is to say, that an absorption machine will use 16 tons of fuel where a good mechanical compressor should use 10 to do the same work.

The simplest form of compression apparatus consists of three principal parts, as is shown in Fig. 2: *A*. An "evaporator," or, as sometimes called, a "congealer," in which the volatile liquid is vaporized. *B*. A combined suction and compressor pump, which sucks or, properly speaking, "aspirates" the gas or vapor from the evaporator as fast as formed. *C*. A liquefier or, as commonly called, "condenser," into which the gas is discharged by the compressor pump, and under the combined action of the pump pressure and cold condenser the vapor is here reconverted into a liquid, to be returned to and again used in the congealer.

The operation of a refrigerating machine, as is illustrated in Fig. 2, is as follows:

The apparatus having been charged with a sufficient quantity of pure ammonia liquid, which we will for simplicity assume to be stored in the lower part of the condenser *C*, a small cock or expansion valve controlling a pipe leading to the congealer or brine tank *A* is slightly opened, thus allowing the liquid to pass into the evaporator coils. These coils, by the way, really perform the same office as a tube or flute in steam boilers, and have precisely the same function, and may be called heating or steam-making surface. The amount of water capable of being boiled into steam in a boiler depends upon the square feet of heating surface, temperature of fire, and pressure of steam, and the same is true of the capacity of heating surface presented by the coils in the evaporator. The heat is absorbed or transmitted through the coils from surrounding substance to the ammonia liquid, which is boiled into a vapor the same as water is boiled into steam in a steam boiler, the surrounding substances parting with an equivalent amount of heat and thus becoming cooler, the amount taken up

and made "negative" being in proportion to the pounds of liquid ammonia evaporated.

As the gas begins to form in the evaporator, the compressor pump *B* is set in motion at such a speed as to carry away as fast as formed the gas which is discharged into the condenser under such pressure as will bring about a condensation and restore it to the liquid state, the operation being continuous so long as the machinery is kept in motion.

To utilize the cold thus produced for refrigerating, two methods are in general use, one of which is called the brine system, the other is known in the trade as the direct expansion system, both of which I will now proceed to explain at some length.

In the brine system the ammonia-evaporating coils are placed in a tank which is filled with strong brine made of common salt, which is well known not to freeze at temperatures as low as zero.

This is the brine tank or congealer *A* (Fig. 2). The evaporating or expansion of the ammonia in these coils robs the brine of heat, as heretofore explained, the process of storing cold in the brine going on continuously and being regulated as required at the gas-expansion valve.

To practically apply the cold thus manufactured, the chilled brine or non-freezing liquid is circulated by means of a pump through coils of pipe, which are placed on the ceiling or sides of the apartments to be refrigerated, the process being analogous to heating rooms by steam.

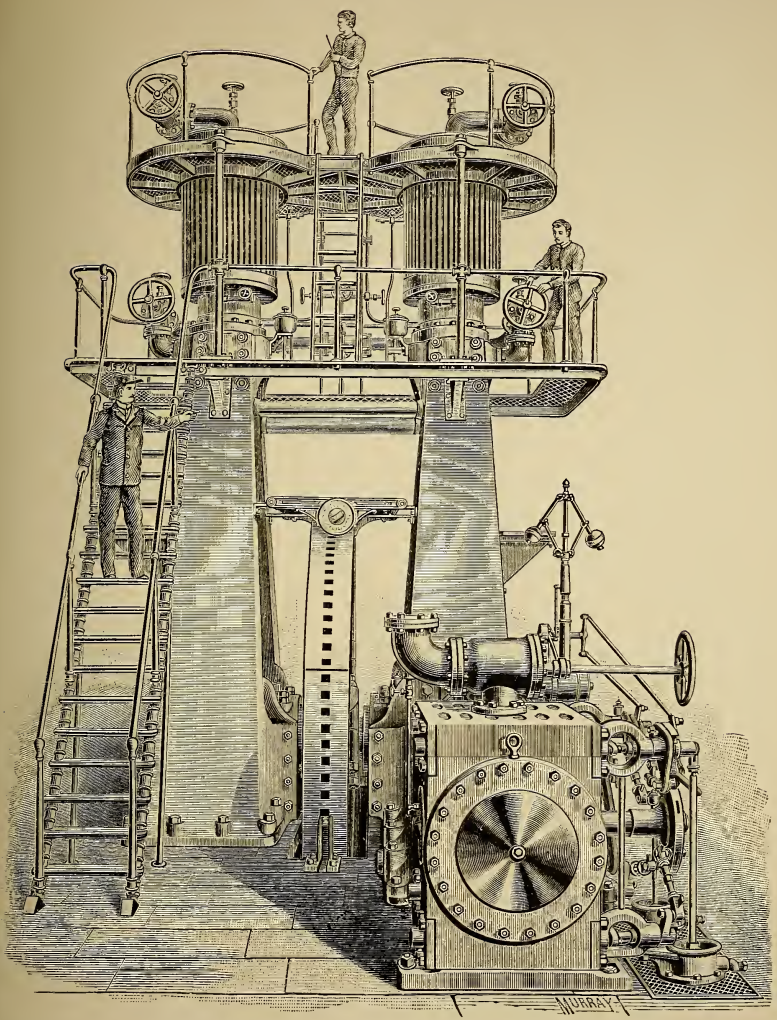
The cold brine in its circuit along the pipes becomes warmer by reason of taking up the heat of the rooms, and is finally returned to the brine tank, where it is again cooled by the ammonia coils, the operation, of course, being a continuous one.

The circulation of cold brine in the rooms possesses some advantages that are not common to the direct expansion system. It requires less ammonia to charge the brine system, hence lower first cost for this important item of expense. There are fewer joints required, and therefore fewer chances for leakage and loss of ammonia, which if it should occur in the direct ammonia system, in a cold-storage room for instance, in many cases life would be endangered, and beer or other material spoiled by the escaping gas, while the entire charge of ammonia would probably be lost.

In the brine-circulating system a very compact and simple arrangement of machinery and tanks, all contained in the engine room itself, can be had right under the eye of the engineer, making it more convenient to care for and manage. But one of the greatest advantages is derived from the fact that, after the machine has been engaged in cooling the large body of brine during the day, it can be stopped, and this reservoir of cold (accumulated in the brine tank while the time the machine was in operation) can be circulated by the brine pump during the night with only a slight loss of temperature, thus keeping the rooms and apartments always at the required temperature both day and night, with the machine really running but part of the time. This is the most important economy, as it reduces the coal bill and avoids the expense of night engineer and fireman, and particularly in the case of repairs and adjustments is of special value, besides giving you a large reserve of power. To realize this saving to the fullest extent, machines of ample capacity with large brine tanks should be used.

In the direct-expansion system the expansion or evaporating coils are not put in brine tanks, but are placed directly in the rooms to be refrigerated, and the ammonia is evaporated in the coils by coming in direct contact with the air in the room to be refrigerated, no evaporating tank being used.

In this system, however, the instant the machine is stopped that instant it ceases to refrigerate, and the apartments being chilled, have then nothing but the frost on the pipes to depend upon for supply of cold; this ice or frost is soon melted and disappears from the pipes and fills the rooms with moisture, and, as a consequence, the rooms become wet and rapidly rise in temperature. To avoid all risk it really necessitates putting in two direct ammonia machines, one of which is held in reserve in case of accident.

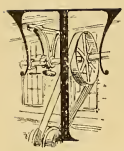


A MODERN REFRIGERATING MACHINE. CAPACITY, 150 TONS OF ICE DAILY.

STEAM POWER AND THE COAL BILL.

NO. II.

By Thomas Pray, Jr.



THE only units recognized by the user of steam power can be easily and tersely expressed as $&c. and I.H.P. Around these prominent ones gather, in intimate connection and inseparably, some others which we must determine the value of, and the amount present, in order to ascertain why our horse power costs either so many or so few dollars for a certain number of hours per week, or as the case may be.

The writer, years ago, took the position that "the cost of an I.H.P. in anything but fractions of a cent per hour should not be allowed." Pounds of coal, per I.H.P. per hour, is a meaningless and indefinite "term," and the experience of more recent practice has shown the force of that position. The extreme variations in the value of any other comparison is fully shown by the lack of authentic record of some of the ever-present factors which make great variations in the actual fact of the cost of a horse power per hour.

The amount of water carried over in steam from the boiler is one of these. Among the notable instances of lack of definite information in pages of tables of results is one in which over one hundred so-called tests were tabulated to show the evaporation of various boilers, in which only two or three of the whole number contain any reference, direct or remote, to the calorimetric value of the steam produced in the evaporation of "so many pounds" of water to one pound of coal or combustible.

Then the methods pursued by some people in determining this most important feature of the required and important data is open to the gravest doubt as to accuracy, the more especially when the data from which apparatus-makers or sellers wish us to take their statements are from insignificantly small apparatus, working upon very small quantities of steam or water, and the apparatus used is subject to very large ratios of error, from almost minute errors of observation at the instant, or from fluctuations of conditions during the interval of time between the points of data-taking, none of which were within a considerable range of the actual result at the instant of "data taken."

Yet, by the use of reliable apparatus, used with care and without reference to "somebody's pattern," we may go on, day after day, measuring the calorimetric value of steam, with variations of no more than ½ to 1 per cent. of each other,—say by two different methods and by two men,—finding from a fraction of 1 to plus 20 per cent. of water present near the engine. In some cases where apparatus for taking out this water has been put into the supply-pipe, we find conditions which aggravate what it was supposed to cure.

Within a year the writer has taken out from two steamships an appliance which was supposed to eliminate the water, but which did also eliminate over 600 horse power. This was not the fault of the construction of the apparatus, but because it was not sufficient in capacity to conduct the steam required for the engine. This result was reached by increasing the percentage of moisture, not decreasing it as it was supposed to do, and, of course, in each case increasing the cost of each horse power and diminishing the efficiency of the engines, by reducing the initial pressure and, consequently, the power to an extent, as tests showed, of over 22 per cent.

It would be no more misleading to the steam user to say that steam separators, by whatever name they are called, would be dangerous to all applications, as in this case, or that they are a disadvantage to an engine of over 20 per cent. than it would be to say the evaporative efficiency of a boiler is fairly shown by its record of quantity *without* careful

tests of the calorimetric value of the steam. Either statement, without the full facts, would be misleading and equally unreliable upon which to base any sort of computation or comparison.

Having, then, assumed that the real factors are known and the relative ones are obtainable, we can seek for the reason why one steam plant of about the same I.H.P. using coal at double the price per ton of another plant may yet furnish its H.P. at less dollars and cents for the same number of hours. This can never be done by any single comparison of the price of coal per ton, or the indicated H.P. from the diagrams occasionally taken, and assumed to be for once a day a fair average of the actual H.P. for all the hours of the day.

The reason why one engine uses coal, say at $4.20 per 2000 lbs., and another at $2.20, and yet the higher-priced coal costs less than the lower-priced for one I.H.P. per hour, is not found in the cost of coal, the steam pressure carried on the gage, or by the patent name-plate on the boiler. It is determined by comparison of a number of essential factors that are all present in some form or other in every steam plant in use. They are part and parcel of each one, and whether recognized or not they are there.

In this article no attention will be paid to the high-speed engine, but the writer will confine himself to what we will call the mill engine.

For the purposes of comparison the writer will introduce here the standard units of a few recognized factors, and briefly show the possibilities of the agent with which we are dealing :

1 H.P. = 33,000 pounds 1 foot high 1 minute. 1 Joule = 772 units of work or heat required to raise one pound 1 foot high, or "the mechanical equivalent of heat," and the unit of evaporation=966.1 British thermal units. Good anthracite coal is known to have from 14,400 to 14,500 heat units in each pound. Then it is easy to ascertain in simple terms what we could do if only the conversion of heat or energy from one to an another material or purpose could be accomplished without loss, and that being done, we are in a condition to know the two extremes of our proposition, viz : possible cost and actual cost, and incidentally what sources of waste exist and how to discover them.

If 33,000 lbs. in one minute make a H.P. and 772 pounds make a heat unit, then the larger by the smaller equals the heat units to make 1 horse power one minute, or 42.746 ; and if we multiply this by 60 it will give us 2565.76, the heat units needed to make one H.P. an hour. If we divide the last result by the number of thermal units required to evaporate one pound of water into steam, we get 2.6558 as the number of pounds of water that should make a horse power for one hour if we did not lose by conversion of the heat into power.

Then, as we know the value of coal, if we divide the heat units in one pound of coal by the heat units needed to turn one pound of water into steam, we will find how many pounds of water should be evaporated with one pound of coal if there were no loss, and we find that 14,500 ÷ 966.1 = 15.082 pounds of water should be turned into steam with one pound of coal. Having now determined the number of pounds of water needed to make a horse power as 2.6558, and the pounds of water it is possible to evaporate with one pound of coal, we can easily determine the amount of coal per horse power per hour required thus : 2.6558 ÷ 15.083 = .176078 pounds per hour, or 5.6793 I. H. P. per hour on one pound of coal ; that is, if we had no losses in turning our coal into power, we should get nearly 6 H.P. per hour on a pound of coal. Nothing like this can be done, for the simple reason that no transformation of heat into work can be effected without very considerable losses.

The factors absolutely necessary to be known with accuracy in order to make the computation properly are as follows. No one of these can be omitted unless an element of doubt is admitted to the final result :

Coal per one I.H.P. per hour.
Cost of coal per ton.
Pounds of water per I.H.P. actual per hour.
Evaporation per pound of coal.
Total H.P. or average H.P. for time noted.
Calorimetric conditions at boiler and at engine.
Absolute initial and terminal pressure.

Conclusions to be drawn for a correct comparison as to cost of one H.P. one

hour, between different steam plants, the data named being given :

Cost of one H.P. 1 hour for coal, in mills.
Cost of one I.H.P. 24 hours for coal, in cents.
Cost of total load per hour for coal.
Cost of pounds of coal per hour and 24 hours, in cents.
Pounds of water per I.H.P. 24 hours.

The value of coal as combustible is of interest, and gives much information, when the ash and refuse varies, as it frequently does in moisture, clinker, etc., from 3½ to 20 per cent., but this is not a matter of positive requirement.

Two diagrams are introduced to show the contrast in the use as well as cost of steam power. Fig. 1 is from a Corliss engine built by George H. Corliss, having been run for over twenty years at their preaching is based. The owner of the plant from which Diagram No. 2 was taken had been running it with an exhaust back-pressure of 14 pounds above the atmosphere for heating and boiling the dye vats, on the principle of getting his power for nothing, using the engine as a "reducing valve" (?).

The actual initial pressure in the steam pipe of Fig. 2 is higher than in Fig. 1, while the cost per ton of coal was nearly 30 per cent. more in Fig. 1 than in Fig. 2. The amount of water used and the evaporation per pound of coal are a curious study, and when the calorimeter data is shown, the reason of some of the waste of coal is easily seen, while if this data had not been included there would be

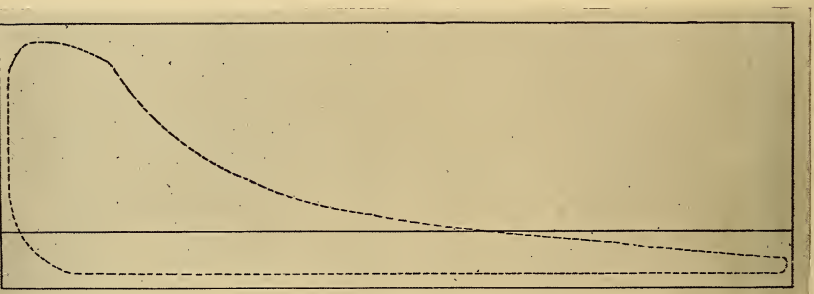


FIG. 1.—FROM A CORLISS ENGINE.

the time the original diagram was taken. Fig. 2 is from an engine run with throttling governor exhausting into the open air. The critical reader will at once say it is not a fair comparison to choose such an ancient type as this and to compare it with a condensing engine. The writer is discussing actual facts for the deliberate judgment and benefit of users of steam power, not ideas or the flight of theory. This choice of data is from actual machines, and each one in place, to keep a manufacturing plant in motion ten or more hours a day for commercial purposes. The engine from which Fig. 2 is taken represents the preference and the practice of a great many persons to-day in the use of steam, and those who prefer this style of an engine back up in practice the ideas upon which no definite or accurate accounting made in the computation, for a large portion of the great cost of No. 2 as compared with No. 1, and here is another and an important element, bad piping. Where a variety of purposes is included in the design of the pipes, so as to embrace heating and drying, as well as power to drive with, like most other combination tools, what is gained in variety is more than lost in directness of effort and in the application of forces, as far as cost is considered. In this case there actually existed such a network of pipes as would be almost impossible to trace, while from all the corners and points drafts were taken from the main pipe, and the engine was as far as it could be (and yet be in the yard) from the boiler, while in Fig. 1 the pipes

were direct, ample in size, thoroughly covered, and not made up of "pieces from the scrap-pile and junk-yard."

The boilers in No. 1 are horizontal tubular, set with common sense. In 2 they are one of the most used and best of water tube boilers in the market, and the fires burned under the pressure of a fan-blower. Economizers were in the flue, and the whole plant was a study in "how not to do it with economy." The owner of the plant was a money-getter, but not in the least by the engineering talent developed in his establishment. The following table gives the needed facts for a comparison of the two plants:

The writer has found in his practice that with a fair amount of skill one I. H. P. can be furnished at $6.80 for 3080 hours for coal, in plants of 250 to 300 H.P., and in larger plants for less. On this basis the throttling engine plant, as shown by the record, costs $11.92 more per H.P. each year than it should. Can the owner afford to go to this expense to gratify his ideas of what in his own opinion such a steam power should be? It is not often that any business concern can afford to pay a bonus of 135 per cent. over the necessary cost of his steam power unless his profit is more than the most of us realize on invest-

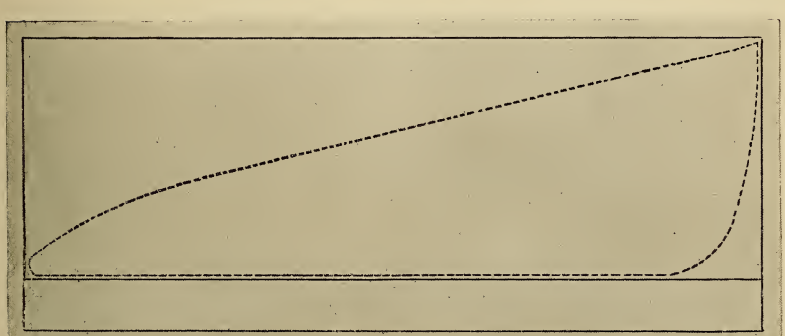


FIG 2.—FROM ENGINE WITH THROTTLING GOVERNOR.

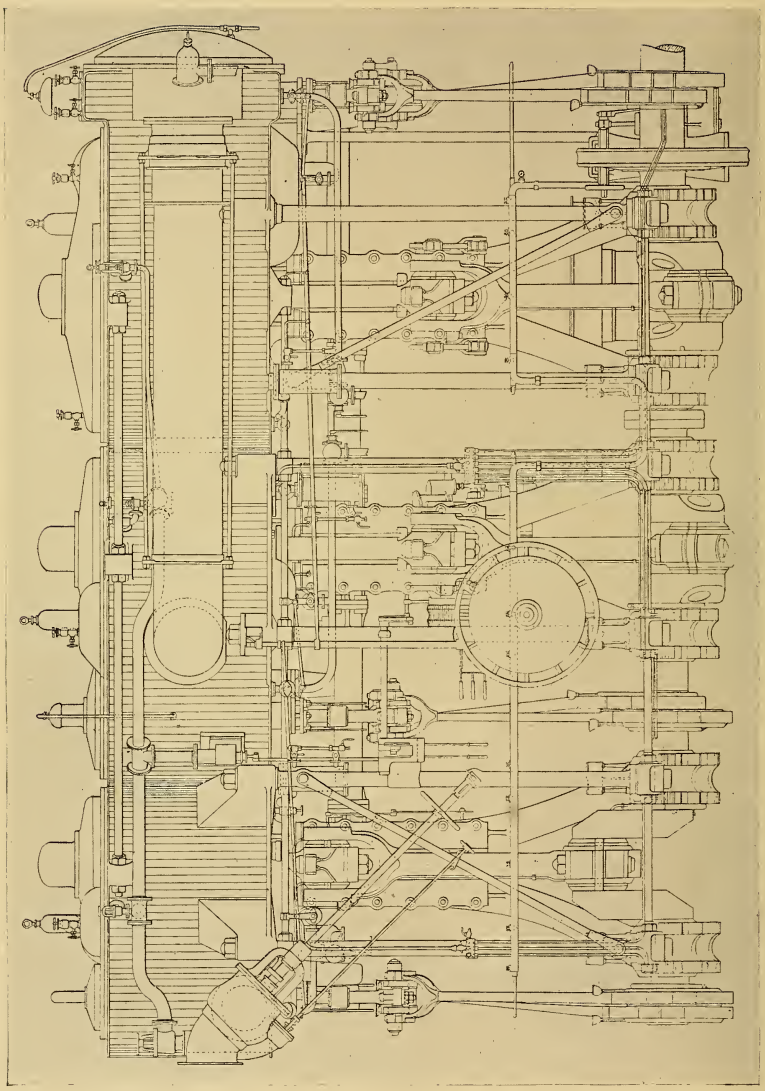
COST OF A HORSE POWER OF STEAM.

	Diagram No. 1.	Diagram No. 2.
Coal per hour per H.P., pounds..	2 28	6.05
Cost of coal per ton.....	$2.90	$2.25
Pounds of water per I.H.P., actual	16.84	47.99
Evaporation per pound of coal...	10.31	7.92
Initial steam pressure, absolute..	83.60	94.60
Terminal pressure, absolute.....	8.71	17.20
I.H.P. average of 10 hours.	151.00	159.00
Cost of one I.H.P. 1 hour (coal), mills	2.59	6.077
Cost of one I.H.P. 24 hours (coal), cents.....	6 216	14.58
Cost per hour (coal) total load (third line above), cents.....	39.00	96.62
Pounds of coal per hour for load	344.00	961.95
Pounds of coal per 24 hours per H.P.....	54.72	145.20
Pounds of water per 24 hours per one H.P.....	404.16	1151.76
Water in steam by calorimeter at boiler, per cent.....	2.16	2.26
Water in steam by calorimeter at engine.....	3.04	21.16
Comparative cost of one H.P. same time.....	$1.00	$2.36
Actual cost of one H.P. one year,—308 days, 10 hours.	$7.98	$18.72

ments. But this is a sample of many plants that exist.

To the steam user the facts as they stand are that each 100 horse power for one year's work, 3080 hours, costs, as shown in Fig. 1, $1074 *less* than that as shown in Fig. 2. In other words, the *excess* of cost in the plant from which Fig. 2 is taken is more than the power could be furnished for with a good plant.

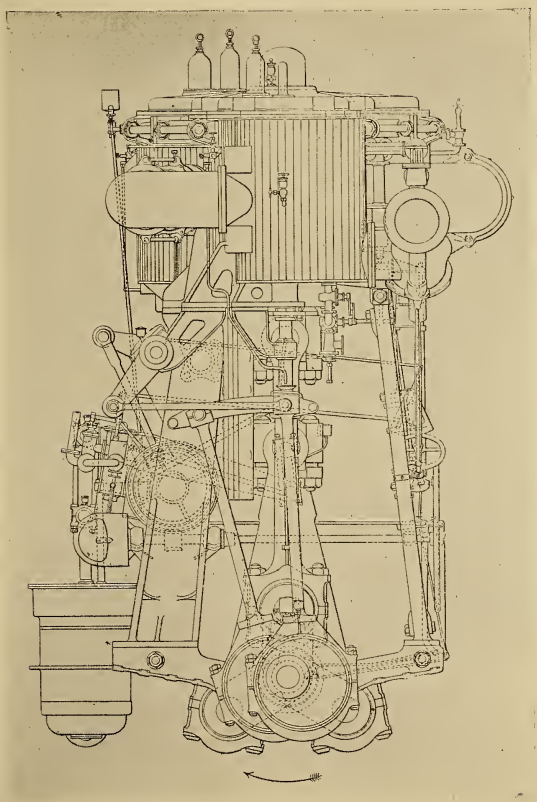
The modern uses and extensions of power call for special skill and experience in the application of the required power to the circumstances, and that is the experienced engineer's realm,—to do the most with the least,—and not to consider the first cost so much as that nightmare in so many cases,—"the perpetual maintenance."



FRONT ELEVATION OF TRIPLE-EXPANSION MARINE ENGINES FOR H.M.S. NAIAD. BUILT BY THE NAVAL CONSTRUCTION AND ARMAMENT COMPANY, BARROWS-IN-FURNESS, ENGLAND.

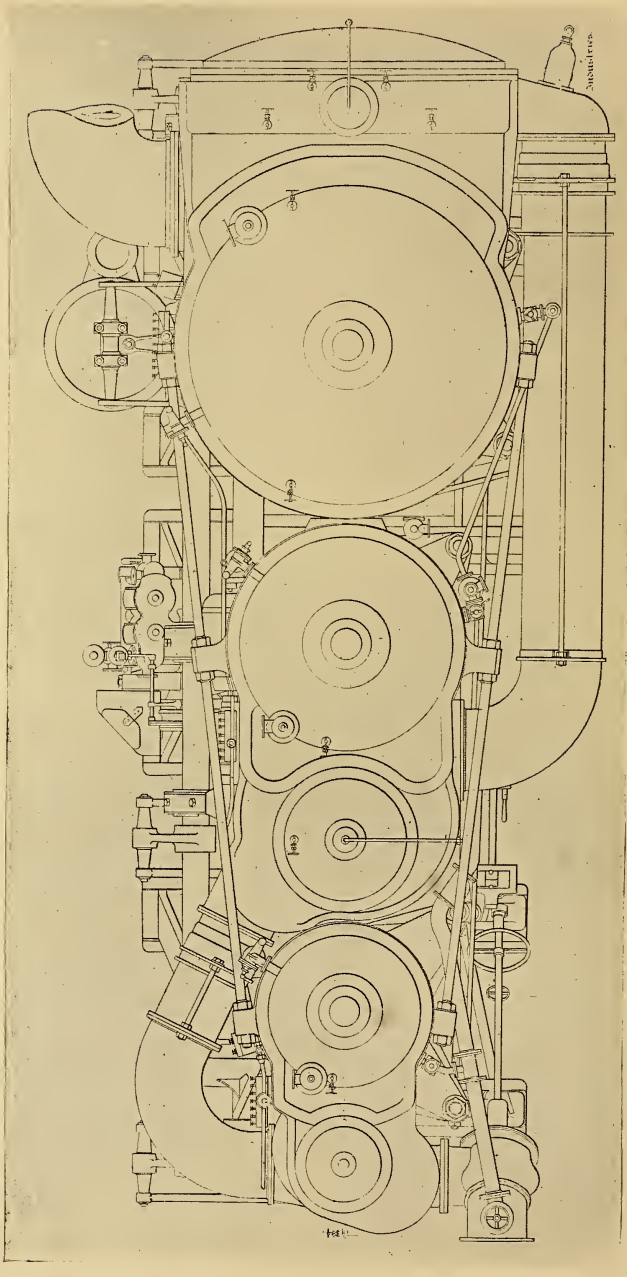
TRIPLE-EXPANSION MARINE ENGINES.

THE triple-expansion engines, illustrations of which are shown on the pages opposite and following, were built by the Naval Construction and Armament Company, Limited, at Barrows-in-Furness, England. Our engravings were made from drawings in *Industries*, and the following particulars were obtained from the same source. The *Naiad*, a new English war vessel, is one of seventeen twin screw vessels being constructed by private contract for the English government, two others, the *Melampus* and *Latonia*, built by the above firm, having already been delivered.



END ELEVATION OF ENGINES OF H.M.S. NAIAD

The leading dimensions of the *Naiad* are common to the other two vessels, the length being 300 feet; beam, 43 feet; and depth to the upper deck, 22 feet 9 inches; the displacement at the mean draught of 16 feet 6 inches being



GENERAL PLAN OF ENGINES OF H.M.S. NAIAD.

3400 tons. The stem and stern frames are of cast steel, with apertures to admit torpedo tubes. The vessels are provided with double bottoms, which under the engines and boilers are used as fresh-water feed tanks for supplying the boilers. There are sixteen transverse bulkheads extending to the upper deck. The protective deck, formed of 1-inch steel plates on the flat part and 2½-inch steel plating on the slopes, extends throughout the ship to 4 feet below the water-line, covering the boilers, magazines, and torpedo rooms, and partially enclosing the engine space. The crown of the deck is one foot above the water-line.

The vessel has been divided into eighty water-tight compartments, and for the better protection of the engine room an armored breastwork is built round it, which extends from the protective to the upper deck. This breastwork is formed of ¾-inch steel plates, with a teak backing 7 inches thick, this being faced by 5-inch steel armor-plating. The accommodation for the officers is aft, the cabins being sufficiently roomy, and below these is accommodation for petty officers. The full complement for each ship is 252 officers and men. Placed in two separate stokeholds are five boilers for supplying steam, of which three are double-ended and two single-ended. There are in all twenty-four furnaces, each with a separate combustion chamber, the total heating surface being 15,880 square feet and the grate area 580 square feet—giving about 16 H.P. for each square foot of grate area. Under ordinary cruising conditions natural draught will be used, but for warlike operations forced draught will be brought into use. For this purpose there are in each stokehold two fans driven by Brotherhood engines, which can maintain a pressure equal to 3 inches of water. The propellers are of gun-metal, and are 13 feet diameter, the blades being fitted to allow of variation of pitch. The shafts are of hollow steel, and are carried in steel brackets. There are two compound-wound dynamos, each capable of giving 300 amperes at 80 volts, coupled direct to steam engines, and on these the entire artificial lighting of the ship depends.

The engines, which are built from designs by Mr. A. Blechynden, are of the type usually adopted in war vessels at the present day, being designed with the object of obtaining the maximum of strength from a given weight of material. They are of the triple-expansion type, with cylinders 33½-inch, 49-inch, and 74-inch diameter, by 39-inch stroke, and are required by contract to develop 7000 H.P. with the boilers worked at an air-pressure of 5 inches of water, and 9000 H.P. with an air-pressure of 1.25 inches, the revolutions at the latter power being 140, and the boiler-pressure 155 pounds per square inch.

On the trials, which in the cases of all the three ships were carried out at Portsmouth, these powers were exceeded, in all cases everything working in a uniformly satisfactory manner, so that no hitch of any kind in the machinery caused loss or delay in a single trial. A summary of the results obtained on the various trials with the three vessels is given below :

Vessel.	Eight Hours' Trial. Steam.	Revs.	Power.	Four Hours' Trial. Steam.	Revs.	Power.
Latona.....	151	136.8	7,251	152	145	9,438
Melampus..	147	135.5	7,656	146.7	140.5	9,093
Naiad.....	153	136.2	7,521	150	145.68	9,250

These results are in all respects highly satisfactory, as it was evident on the higher-power trials that the powers obtained could have been considerably augmented, as on the last three half-hours in the *Latona's* and *Naiad's* trials the powers were over 9800, while the contract power was exceeded in some cases by more than 1000 horse power. Trials were made over the measured mile only in the case of the *Latona*, when the speed was found to be with the lower power 19.05 knots, and 20.2 knots with the higher power.

A comparison of the size of these engines with those being constructed for the new U. S. cruiser *New York* may be of interest :

	Size of Cylinder.			Stroke.
	High.	Int.	Low.	
Naiad.....	33½-in.	49-in.	74-in.	39-in.
New York.....	32-in.	46-in.	70-in.	42-in.

The power to be developed is about the same in both vessels.

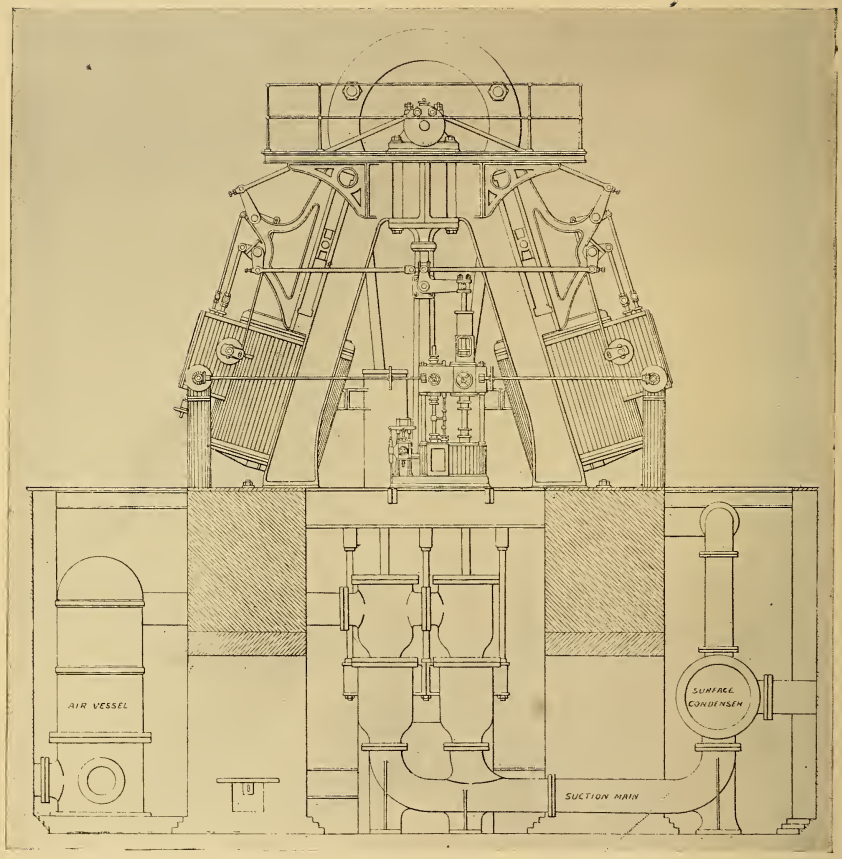


FIG. 1.—TRANSVERSE SECTION OF "DAVEY" CORNISH PUMPING ENGINE. BUILT BY HATHORN, DAVEY & CO., ENGINEERS, LEEDS, ENGLAND.

NEW CORNISH PUMPING ENGINES.

A PAIR of pumping engines which have recently been erected in Wolverhampton, England, on account of their novel construction have attracted considerable attention. That our readers may obtain a good idea of their design and construction we have abstracted the following description from that well-known English periodical, *Industries*, from which we also obtained the drawing used in making our engravings :

"The new works comprise a well sunk in the red sandstone to a depth of 140 feet, communicating with a bore-hole to a greater depth, and the installation of the pair of engines illustrated by us on pages 170 and 172. The works have been designed and carried out by Mr. Lyons Wright, C.E., the engineer to the corporation. The well yields 4,000,000 gallons of water per day. Referring to our illustrations, Fig. 1 shows a sectional elevation, while Figs. 3, 4, and 5, herewith, represent diagrams taken from these engines. They have been designed by Mr. Henry Davey with a view of obtaining as high a duty as possible from low-pressure steam ; in fact, to get the advantages of an ordinary Cornish engine working against a constant load applied to an engine working against a varying resistance. The engines have been constructed and erected by the firm of Messrs. Hathorn, Davey & Co., Leeds, and are the first that have been built of the particular design adopted—that is, one with two low-pressure cylinders.

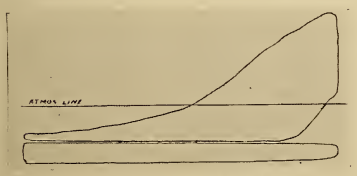


FIG. 3.—FROM WELL ENGINE.

"The engines are of the non-rotative type. Each engine itself consists of two cylinders, 56 inches diameter by 5 feet stroke. These are placed at an angle to each other, and have each the Cornish system of steam distribution—that

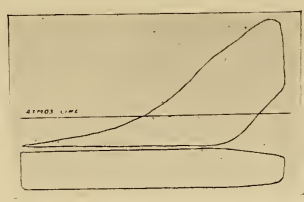


FIG. 4.—FROM WELL ENGINE.

is to say, the steam is first admitted into the cylinder and expanded, then passed over to the opposite side of the piston, and afterward exhausted into the condenser. This distribution of

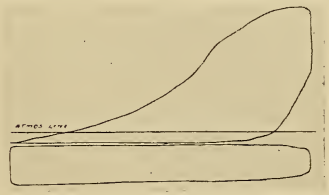


FIG. 5.—FROM FORCING ENGINE.

steam is claimed to be a great source of economy, owing largely to the fact that the working sides of the piston and cylinder are not exposed to the cooling influence of the condenser. The Cornish engine, as is well known, has always given a higher duty with low-pressure steam than any other class of engine, especially in mines, where the conditions of its application are favorable to expansive working, because of the great mass of the pump-rods put in motion. In water-works, however, the conditions are not so favorable to expansive working as in the case of mines ; consequently expansion cannot be carried to so great an extent. Again, the principle of the ordinary Cornish engine is that of lifting a load by the expansive force of

steam, and then allowing that load to raise the water during its fall. The Cornish engine is, therefore, not well adapted to conditions where the resistance varies. In pumping from a well the load varies necessarily with the level of the water, and that level again varies with the rate of pumping. These are important difficulties to be overcome in applying Cornish engines to water works purposes. In the Wolverhampton well the water level varies more than 100 feet. This made the difficulties to be overcome still greater than in ordinary wells, where the fluctuation of level is much less than in the present case. The engines under notice are adapted to great variations of load and water level, whilst expansion can be carried to any required extent.

"The novel feature in these engines is the arrangement of the cylinders and pumps relatively to each other in such a manner that whilst the leverage of the disc of the steam cylinder remains fairly constant the leverage of the pump varies. Thus the ratio between the two leverages is constantly varying, and advantage of this is taken by Mr. Davey to secure expansion in the steam cylinder at the moment when it is most suitable. The piston rods of the steam cylinders are, as will be seen, coupled to a pair of reciprocating discs by means of pins, from which rods descend to work the pumps. The steam and pump pistons are thus connected together in such a way that the steam piston gets a mechanical advantage over the pump piston as the stroke is produced. In other words, the velocities are equal at the beginning of the stroke, but the relative velocities vary as the stroke proceeds, the velocity of the steam piston being the greater of the two. The engine thus meets the varying requirements of water-works in the most economical way, and is at the same time under perfect control. This is accomplished by dispensing with the counterweight of an ordinary Cornish engine, and utilizing the expansive force of the steam on the steam piston to the pump through the medium of the disc, which acts really as a bent lever in such a way that the resistance of the pump virtually decreases throughout the stroke. That this is done may be seen from an inspection of the diagrams given on the preceding page taken at the starting of the engines. There are two engines, one being employed in pumping from the well to the surface, and the other in forcing the water to an elevation of 300 feet to the storage reservoir. The well engine raises by means of two open-top 27½-inch bucket pumps 2900 gallons of water from a depth of 140 feet at 12½ strokes per minute. The forcing engine is made from the same patterns as the well engine, but its pumps are smaller on account of the greater lift. It raises 1500 gallons 300 feet high at 13½ strokes per minute. The two diagrams, Figs. 3 and 4, were taken from the well engine, and that shown in Fig. 5 from the forcing engine. Figs. 3 and 5 are made to the scale of 1-32 inch, and Fig. 4 to a scale of 1-24 inch. The engines are regulated by the well-known Davey differential gear. It will be noticed that the engines are perfectly balanced, and can move only under steam.

"The new engines replace a pair of ordinary Cornish beam engines, which will be kept in reserve. The new engines, besides doing the work recently done by the old engines, also do the additional work involved by the new sinking. They take their steam from the same boilers which were used for the old engines, no extra boilers being required for the additional work. It is worthy of remark that, although the boiler pressure is only 30 pounds per square inch, the guaranteed duty is 93 millions on 112 pounds of good coal. At the official start the engines did their work in a satisfactory manner.

"The pumping during the completion and sinking of the well was done by the well engine, the pumps being slung. The engines and pumps are good specimens of modern engineering water-works practice."

The low pressure and general form of construction in this plant is so radically different from the practice as employed by leading Americans engineers, that we will wait with interest reports of the official tests and will print such further particulars as soon as we can obtain them.

THE STATIONARY ENGINEER.

By Leonard A. Blake, Ann Arbor, Mich.

ENGINEERING, generally speaking, is that art of designing and superintending the execution of works of a constructive character, such as roads, bridges, harbors, railways, canals, docks, works for supplying water to towns, drainage and sewerage works, mining machinery, and the working of metals. But we shall deal with that distinct profession which is said to have originated about the middle of the last century. From that time the improvements in the steam engine by James Watt for raising water by means of the expansive force of steam, its subsequent application to the railway system by George Stephenson, and its first successful adaptation to navigation by Robert Fulton have given to civilization and commerce a great impulse, which in their turn have created a necessity for the wonderful, magnificent, and numerous engine works of the modern times.

Indeed, steam engineering has assumed such large proportions that it has opened a field for a profession the boundaries of which are hard to define. It requires a wide range of scientific knowledge to understand and explain the laws of nature involved in the performance of the engineer's daily work. There always has been and probably always will be two classes of mechanics,—those who stand at their benches and go through the manual motions of their work like automatic machines, with little more conception of why the results are as they are; and the other that class of men who make no moves without knowing the why and wherefore of, results, and the relative importance of each step. This, the mechanical education that schools the mind to a clear comprehension of the principles, equally with details, and leads unfailingly to that higher field where diligence, marked ability, and skill find their natural level.

Just so with the two classes of engineers,—practical and theoretical engineers. Our practical men sneer at our theoretical men, and *vice versa*. While we have men in our profession who would shed luster on any calling, we have many who are very slack in the real knowledge so essential to their profession, and often this last requirement is the cause of the frequent recurrence of accidents, by which so many lives are sacrificed and property wrecked, although not always, as carelessness and poor machinery have a great deal to answer for. Carelessness is too often the cause. In May of 1889 the Des Moines court-house had a narrow escape from an explosion. The night man left the fire burning low. When the day man came on in the morning, he commenced firing up strongly. Not noticing the stage of the water, he went home to breakfast in about half an hour's time, leaving a heavy fire. In his absence some of the domestics needed some hot water in the kitchen and opened the valve for that purpose, but could not get any. On investigation the boiler was found to be empty and red-hot, with all the flues burned loose.

It is a great mistake to intrust the care and management of machinery to persons of inferior judgment. A competent engineer can often save three or four times his wages in knowing how to take care of the property intrusted to his care. Just what capabilities a so-called competent engineer should possess would be more difficult to enumerate than those he should not. The engineer, like the physician, must always be

NOTE.—In order to encourage working engineers in their efforts to advance themselves in the knowledge of their profession, as well as to communicate their views, ideas, or experiments to each other, the publishers of CASSIER'S MAGAZINE have offered a prize for articles written by engineers in charge of steam plants. The articles printed will be carefully revised, so that no one need be debarred from the contest on account of the idea that his contribution may not be properly written. We wish as far as possible in these articles to print facts of interest to stationary engineers. The only conditions we make are that the writer must be an engineer, in charge of a steam plant, and that articles be written only on one side of the paper. In accordance with this offer the writer of the above article, "The Stationary Engineer," has been awarded the first prize of ten dollars in gold. The writer of the following article, "Feeding Water to the Boiler," receives the second prize, five dollars in gold. We trust that this monthly competition will be the means of eliciting much information which will be found valuable to engineers in charge of steam plants.—ED.

qualified for business. In most other occupations the workman sticks to his line : a broommaker will do nothing but make brooms, but the engineer's line covers a wide range.

Not every engine has had an indicator applied to it to show its condition, but there is always one, two, three, or more indicators on every engine that shows the skill and worth of the engineer. Is your engine clean? Are your oil-cups clean and free from dust? Is there no baked grease around the lubricator connections? Is your engineer kind, courteous, obliging? Does he always ask your opinion with a willingness to learn? Or is he gruff, lazy, and greasy, telling you he is no book engineer, but a *practical* engineer, not knowing that these practical men are often a nuisance to the profession : their minds are too small and cramped to accept the enlightenment needed in this progressive age. There is little excuse for ignorance on the subject while so many books are accessible at a trifling expense,—books written by engineers who devoted years to their noble calling, and animated by a desire to bequeath to posterity the knowledge they acquired in order that the *art* of engineering might advance on intelligent and well-defined alignments.

If the practical (?) man referred to would devote a portion of his leisure hours to study and follow a regular systematic course of self-culture, he would eventually acquire advantages that would enable him to compete with men who have had all the facilities of an early education, and might then say, as the Kansas minister said, "I have been a far more useful man since the Lord revealed to me that I was never to be a great man," and he would have learned that no man is practical unless he has proved practice with theory and theory with practice.

I remember reading in an engineering publication, shortly after the Johnstown flood, an article saying that much comment had been occasioned among engineers of this country because President Moxham, of the Johnstown Rail Company, had sent a cablegram to Manchester, England, asking for another engineer to take the place of a Mr. Lewis, who was lost in the flood, as their engine was one of the Galloway make and had to be reversed at a given point, or a great deal of awkwardness would be occasioned. Luckily for the American engineers, he was able to find one engineer who had run a similar engine, and so the Englishman did not have to pack up and come to a country where there are scores of men who, although they had never seen an engine of this kind, could have overcome the difficulty in far less time than it takes to cross the Atlantic.

An engineer should be possessed of natural talent, not necessarily be a machinist. I think but few of our great inventors, such as Watt, Stephenson, Fulton, Stevens, Evans, and many others, were machinists.

James Watt, we can almost say, was the inventor of the steam engine ; at all events, the improver. He was twenty-three years of age before his attention was called to the capabilities of steam as a motive force.

Robert Fulton was first apprenticed to a jeweler ; afterward he became a painter of portraits, and later of landscapes. His versatility at length inclining him to mechanics, he devised and patented the inclined plane, invented a mill for sawing and polishing marble, a machine for spinning flax, and one for making rope. The small steamboat that he built and its successful propulsion by the newly-understood power are facts of interesting historical moment and marked the inception of the most significant era in the industrial world.

George Stephenson (his biographers inform us) was humbly born. At the age of fifteen he was appointed fireman in an English colliery, where he applied himself to the earnest study of the steam engine. All through his early life we find a record of a struggle between a determined purpose, industry, sagacity, and the great drawback, poverty. He invented the colliery safety-lamp, he constructed the first locomotive, and soon after he was made director of 214 miles of railroad, involving a capital of £5,000,000.

In a stationary engineers' handbook occurs this statement : "The very nature of steam engineering calls for superior intelligence in those on whom depends the care and management of steam

machinery. Engineers should therefore prepare themselves for any casualty that may arise, by considering possible cases of derangement and deciding in what way they would act should certain accidents occur."

In my place I have not at present all the time I would like for such comprehensive reflection, as the introduction of two new engines, one boiler, and two dynamos recently (the engines being new for the work to which they are adapted) require unusual attention, but the plant is working with increasing smoothness day by day, and careful observation of its several characteristics will probably eventually suggest new ideas of practical moment.

No man who loves exact knowledge can fail to find a scope for the exercise of his intellect in the calling of an engineer, as it is adapted to men of the most opposite temperaments. Two conditions alone are needed: The man must love his work, and have ability to perform it.

FEEDING WATER TO THE BOILER.

By J. W. Power, Secretary N.A.S.E. of West Bay City, Mich.

WHERE is the proper place for the feed-water to enter a boiler? This is a very important question, as on its proper solution may depend the durability of the boiler. If we feed low down, at either end, a stream of cooler water than that in the boiler will flow the whole length of the sheets, which are many degrees hotter than the water, thus contracting the part of the boiler with which it comes in contact, and subjecting the rivets and sheets to very unequal contraction and injurious strain. If cold water is used, it is liable in time to be destructive to the bottom plates. If we feed at the side, we produce the same destructive conditions extended to the flues. If we feed through a mud drum, we have trouble with the drum, either leaking, burning, or rotting. If the drum is set so that it is acted on by the fire, it generally becomes leaky, or burns out in holes on top.

This trouble is caused by the water being prevented from quite filling the mud pipe by the air forming large bubbles on the top of the water, under the top plate of the mud drum, at either or both sides of the nozzle. If several boilers are connected by a mud drum and the feed-water pumped through it, it is continually subjected to contraction and expansion more or less injurious to the battery. My experience suggests invariable feeding at the top. The scientific reasons therefor are here given:

A few years ago I was in charge of a planing-mill engine in this city. One day an agent came into the engine-room and showed me what he called a spray-feed. He claimed that it would feed the water in a thin spray into the steam room of the boiler, and that by so doing the water would be instantly heated so hot as to precipitate its scale-forming deposits in one place, viz: over the nozzle of the mud drum. He sold the firm the device. The next Sunday we cut a hole in the boiler and he put it in to suit himself. I saw immediately that the boiler steamed easier. My fireman was delighted. I supposed the easy firing was owing to the spraying of the water into the hot steam; but the next time I cleaned the boiler I found the spray instrument was broken off and spoiled, so the water was going in as a solid stream. My fireman said he noticed no difference in the firing.

Some of the time I used to do my own firing, and when I did I experimented with the injector and the pump, as well as with hot, cold, and warm water, every experiment giving good satisfaction. I then turned the water into the mud drum. That soon called for wood. This made me do a little thinking, and I came to the conclusion (whether right or wrong) that when water is pumped into the steam it does not cool the water in the boiler; or if it

See note, page 173.

does, it is very little, and the cooling, if any, is very evenly distributed through the mass of water. Neither does it cool the steam perceptibly if fed with care.

The reason I think it does not cool the steam is, steam contains about 960 or 1000 degrees of latent, or insensible, heat, and this latent heat goes to heat the feed-water while passing through the highly heated steam. For instance, if we pump 550 pounds of cold water at 32 degrees, or say ice water, into the steam, it will have a capacity of receiving the latent heat contained in the amount of steam evaporated from 100 pounds of water, that is, if it has time in its passage to absorb the latent heat, or if the cold water is fed into the boiler in a thin sheet. I think that under good conditions the water could be brought to the boiling-point without abstracting any of the sensible heat from the steam. Engineers who are acquainted with the theory of latent heat will see the point of my argument.

However, if we take it for granted that there is a cooling down of both steam and water, the cooling is so evenly done as not to injure the boiler.

Some engineers say it is troublesome to feed into the steam. I found no trouble either with pump or injector, and we carried 90 pounds of steam. I think I ran that way over a year, and will always feed my boilers that way if it is possible to so arrange them.

A PROBLEM FOR STATIONARY ENGINEERS.

By Thomas Pray, Jr., C. and C.E.



THE practical work of engineering deals in produced results, dollars and cents, of cost, for some unit of power, whether turning a dynamo, pulley, a driving-wheel on a locomotive, or a sixty-ton balance-wheel pulley of a 1200 H.P. engine which gives motion to the 40,000 spindles of a print cloth mill, with its 1100 looms.

The general reader does not care to dabble with the details of the daily life of the man who is responsible for the production of a certain result, each day, "as per time table" from the steam plant, but the writer, having been much among working engineers, and knowing how many of them are doing their best to master the principles that underlie the use of steam for power, has prepared the two diagrams on the following page which were taken from the same engine, doing the same kind of work, but with quite a difference in the position of the valves, to determine if the engine could be made to do the same work with an expenditure of less steam per I.H.P. per hour. Upon computation it will be found that such a result was produced.

The engine from which diagrams A and B were taken has a cylinder 14 inches in diameter, 16 inches stroke. The clearance is equal to 1.252 inches of the bore, at the end from which the indicator diagrams are shown: Scale of spring 60, speed 104 revolutions per minute.

Question 1. Which diagram will give the horse power with the least pounds of steam accounted for by indicator, and what is that amount per I.H.P. on each diagram?

For this example the work had better be done by measuring the absolute pressure at the line *b*, and to get all who may wish to compete started in the right track the data is partially given here,—*b* on Diagram A = 31 pounds,

NOTE.—Recognizing the great importance of a correct understanding of the steam engine indicator both to the engineer and his employer, the publishers of CASSIER'S MAGAZINE have arranged to print a series of problems similar to this one, which they solicit engineers to solve. As an inducement they will give an award of five dollars each for the first two correct solutions which we receive. The conditions require that the answer contain an explanation of the whole computation, together with the figures. The time a letter is posted, as per date on the post-mark of the envelope, will be considered in making the award. The successful answers will be printed together with the names of the winners. No one but an engineer in charge of a steam plant will be entitled to the award. The problems we believe should prove of much value, as they are intended to instruct, not to amuse.—ED.

and on Diagram B 27.2 pounds,—and as there is quite a difference in the density of steam as given by various tables, I give the correct density of 31 pounds as .0759, and of 27.2 pounds as .07712, and the line *b* on Fig. A = 8.4128 inches of the cylinder filled with steam of 31 pounds pressure, including the clear-

to make one revolution, by the minutes in an hour, and divide that result by the number of cubic inches in one cubic foot; this gives the cubic feet used in one hour.

Then multiply the cubic feet by the density, or weight of one cubic foot, and you have the pounds of steam used in

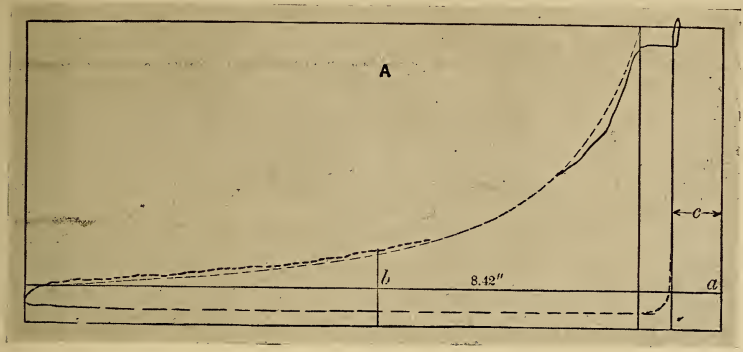


DIAGRAM A.—H.P., 43.808; M.E.P., 32.972; SCALE, 60.

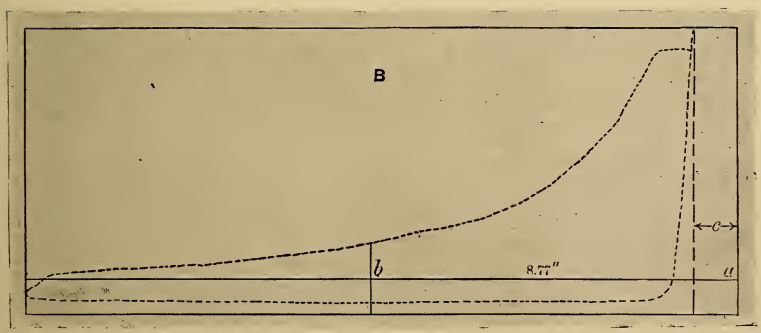


DIAGRAM B.—H.P., 37.396; M.E.P., 28.907; SCALE, 60.

ance, while B = 8.767 inches at a pressure of 27.2 pounds, the I.H.P. of A is 43.808, and B 37.396.

Rule.—Multiply the volume of cylinder to the point of computation in cubic inches (and this means the area of 14 inches multiplied by the distances from *a* to *b* on the atmospheric line) by the revolutions per minute, by the strokes

one hour. Lastly, divide the pounds of steam used per hour by the horse power of the diagram and you have the final result in pounds of steam per I.H.P. per hour, or the first answer.

The writer has selected diagrams of a different I.H.P., and has located the points for computation at different parts of the stroke, in order to give the read-

ers an opportunity to have the different problems, and with the exception of the area of piston, no two items are the same on different diagrams.

Question 2. Taking the final result of A and B as data, this engine runs 132 hours per week at 104 revolutions per minute and at the amount of power shown in A, or 43.808 I.H.P.

How many pounds of coal per week's run will be saved by either diagram over the other if the boiler evaporates eight pounds of water into steam, with one pound of coal, taking the data from the first question, and using the difference in pounds of steam per I.H.P. from which to figure the second result?

To do this requires getting at the amount of steam accounted for by the indicator on each diagram, then getting at what the most economical diagram is, and then how much more economical in pounds per H.P. per hour. The balance will be quite simple. All mathematical or theoretical considerations, except the facts stated, are ignored in this question. The cylinder condensation, indicator errors, etc., are not considered.

Reflections and Observations.

It will probably surprise many engineers to know that in the recent tests of a compound engine that the steam jacket failed to give any appreciable economy. The early tests of this engine, which are described in William Kent's article in this issue, were questioned, and now that the facts have been confirmed—while they do not prove that under all conditions a steam jacket is of little economic value—should, nevertheless, lead to similar tests of other engines under various conditions, so that we will be able to work intelligently in the future. Like many other important subjects, able engineers have different opinions on the matter, just as they differ as to the first point of cut-off, or pressure of steam essential to a small coal bill. It is very likely that under some conditions a steam jacket is of decided benefit. What these condions should be, and the why and wherefore, we hope we will be able to intelligently discuss when further facts are ascertained after exhaustive tests are made.

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With a slow-speed engine or pump, however, the steam jacket shows economy, and the smaller the number of revolutions the greater of course the saving in steam, and, therefore, coal. The Pawtucket engine has had, however, more exhaustive and complete tests than any other engine in this country, and it is possible that the pumping engine designed by E. D. Leavitt for a New England city would under as careful experiments fail to show from 18 to 20 per cent. in favor of the steam jacket, as it did when tested a few years ago. At that time, according to the report made, the fireman, who did not know that the steam jackets were not in use, rushed into the engine room and said he "couldn't keep the steam up," but as soon as the steam jackets were again connected the difficulty was removed.

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As is well known, in theory it did not seem possible to obtain economy by the use of live steam to heat the feed water, and in England the ablest engineers scoffed at the idea; but one of the English technical journals took the matter up, had a thorough test made on a well-known steamer, and the experts reported a saving of from 5 to 7 per cent., a result entirely opposed to theory. These instances show that theory and

practice are not always in accord with each other, and we will no doubt find some day that some pet ideas that *seem* good in practice or in theory, when put to the test, prove either the theory or the practice to be founded on a wrong assumption.

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In the launching a few days ago in Philadelphia of the armored cruiser *New York* the constructive genius of the American mechanic was conspicuously illustrated. The largest vessel ever built in North America,—8150 tons,—as well as what will be the most powerful and the most speedy, being capable of steaming twenty knots an hour,—this latest acquisition to the navy of the United States will, when ready for service, be able to cope with the most formidable battle-ships afloat, a fact in itself flattering to American skill and enterprise, when it is remembered that European nations have for years led the world in naval supremacy.

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But it is not alone in the skill and science displayed in the construction of this superb engine of war that American shipbuilders have recorded a masterly triumph. When such a vessel can be launched fourteen months from the laying of the keel—as in this case—it can no longer be said that the United States is lacking in facilities for creating a modern navy or a merchant marine. Clearly industrial genius has achieved a notable advance in this work. The fact carries with it not only a feeling of patriotic pride but likewise an assurance of national security. It is no longer a question of how, or when, or where to get a navy, but of providing the means. Let Congress take heed. The rolling mills of Bethlehem and Pittsburg and the shipbuilders of the Delaware River may be relied upon to do their part expeditiously and successfully.

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When I wrote last month regarding the fact that the Corliss valve, which it has been claimed was not invented by George H. Corliss, and of his great masterpiece, the Centennial engine, which was not (says Mr. Herreschoff) the product of his brain, I was not aware that even the valve-gear which I had supposed no one disputed to be his own conception was the idea of someone else. A well-known engine builder, whom I met a few days ago, in commenting on the matter, said, "Why, even Corliss's most staunch friends today concede that the 'cut-off,' as used by Corliss, was invented by Sickles." This leaves practically nothing about the Corliss engine which was invented by Mr. Corliss. It is too late to change the name on the thousands of engines in all parts of the world, which it appears should properly be called Sickles-Wright engines. But I cannot help repeating what I said last month, that it is a pity these facts do not come out before the supposed inventor has passed away.

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A well-known engineer has called my attention to the opinion which I expressed in the November number of this magazine regarding college degrees, and inasmuch as he differs with me, I take pleasure in giving his views. He believes that it is well enough for a mechanical engineer to print on his card those words as designating his business, as I suggested, but he objects to its abbreviation to M.E., saying that if the letters only appear they convey the idea of a title granted by a college. Although this objection is perhaps a well-founded one, the fact that for years the abbreviation has been used, and, as I stated last month, the mechanical engineer makes no claim to college degree when he uses the abbreviated form on his business card, coupled with the fact that the public generally understand the initials to mean nothing more than a business designation, I am inclined to think that my view of the matter is correct. I would like to have the opinion of other engineers on this topic, and if anyone can prove to me that a man is not a mechanical engineer unless he has received a college degree, I will willingly back down from the position which I have taken.

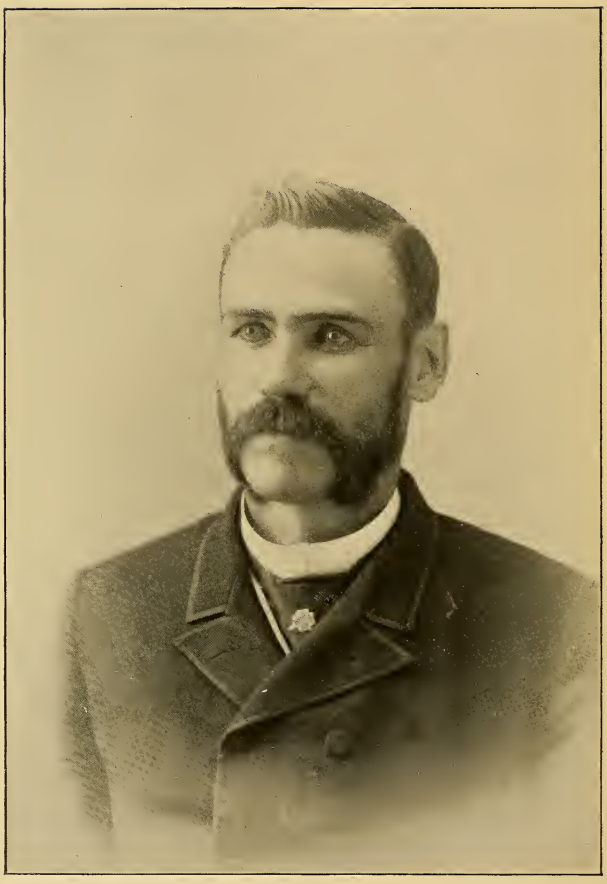
THE molecular changes in metals when their temperature is raised or lowered has been an interesting topic for many years, and while I have had no practical experience to give scientific data regarding the matter, I did have an actual opportunity to discover what I supposed for a time would prove a very valuable contribution to literature on the subject. Like many people who possess a razor, I had one which for years had been a very satisfactory tool by which to remove the hirsutical growth. It was the pride of my heart, and I could not compute its value in dollars and cents. Any ordinary amount would not have purchased that razor. In fact, I had often told my friends that one million dollars would not tempt me. But alas to hopes and expectations! A molecular change made my razor a worthless piece of steel, with which a sharpened farmer's hoe would have been ashamed to compete.

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LAST June I arrived in Providence on the second day of the convention of the American Society of Mechanical Engineers. Every room was taken, but I managed to obtain a cot in a room with a man who I must say was not an engineer. The room was small, and the dressing-case was covered with an assortment of combs, brushes, and toilet requisites. The day I arrived the temperature was about 100 in the shade. I used my razor. I worked it perfectly. The next day, it will be remembered by those who were present, was decidedly cooler. It dropped 30 degrees. I found it necessary to use my razor (unfortunately every twenty-four hours I have to), and after putting it through the usual application on the strop, rubbing it on my bare arm, and getting it into prime condition, I started to shave. I rubbed it with the "grain" of the hair, and I rubbed it against the "grain," but not a hair moved. I stropped it again, but I could make no impression on my beard. Now, said I, here is an actual fact regarding the molecular change in metals, and as that was one of the topical questions at the meeting, I said to myself that I would bring the razor to the hall and give the full facts to the members there assembled. I went out to dinner, and when I returned started to get my razor. I could not find it. I hunted high and low, but the razor had disappeared. The hall-boy crawled under the bed, and looked in the fireplace, but no razor appeared. I rang for the chambermaid. "The razor?" she asked. "Why, yes; the man who had used it sharpening his lead pencils in the morning took it while I was making up the room."

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OF the many pleasant things I have heard about this publication none was more gratifying than a notice which was printed in *Industry*, the leading technical journal of the West, which is edited by John Richards, and published in San Francisco. Mr. Richards writes, "No. 1, Vol. I, of CASSIER'S MAGAZINE is at hand, and is a surprise. First, in commendation, we will say that the promise of the prospectus is more than borne out in the subject-matter, while the arrangement and 'make-up' exceeds any other magazine, secular or otherwise, that can be referred to. In this remark we include the advertising pages, arranged with topical heads, which may be studied with profit by the more pretentious magazines, and it affords us much pleasure to find a technical publication standing at the head in many qualities that are supposedly reserved for 'pure literature.' The improvement in technical literature during ten years past has been marvelous, especially in illustrations and what we will call 'scholarship.' The present magazine is, we believe, wholly written in the third person, as all essays should be, and in a diction and dress that indicate the common character of intellectual acquirement, whether directed to the applied sciences or speculative philosophy. This change in serial technical literature is, we believe, permanent, and has been foreshadowed by the space given to such subjects in the secular magazines during three years past. It is evident that the true and useful may serve the same purpose in literature and serve it better than the ideal and unreal." THE OBSERVER.



R. C. Carpenter

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CASSIER'S MAGAZINE.

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THE TARIFF AND THE CONSTRUCTIVE ARTS.

By Professor R. H. Thurston, Director; Sibley College, Cornell University.



FOR the first time in the history of the nation the political issues and the differences which draw the lines between parties in the United States are to-day mainly economic. For the first time, the "intelligent voter" must be truly so if he would employ his civil right of suffrage in such manner as to give effect to his opinion and intention. The platforms of both political parties are sufficiently explicit, and the attitude of each is well defined. The question to be decided is whether such a system of collection of revenues and such methods of its expenditure are to be employed as will afford protection and encouragement of home industries, or whether the principles of "free trade" are to be accepted as the ruling policy of our government. A second and less well-defined issue for this campaign is the position of the executive branch of the government in regard to the civil service reform movement. The Republican party is pronounced in its support of protection and of civil service reform; the Democratic party favors the collection of our revenues with a view to securing revenue only, and leans toward free trade, and also, by ignoring the civil service reform movement, places itself on the record as opposed to that work of reformation. In the discussion of the first and most prominent of these issues the widest possible divergence of opinion is observed among even those who are presumed to be authorities on the subject, who should be at one and who should be the leaders of the people in the endeavor to take the right course; while the confusion thus produced in the minds of those who are confessedly ignorant of the science of political economy is intensified by the entrance into the debate of many disputants who have neither the knowledge nor the acumen that should be possessed by those who may of right aspire to become leaders and teachers of the voters of the country. The first class should evidently be very cautious in expressing their views in relation to a matter of life and death to their country, such as is this; and the second class should simply be shut out of the discussion or ignored.

Of those who have a claim to be heard in the debate there are two principal classes,—the political economists by profession, and the business men and workingmen who can contribute facts of experience to match the theoretical considerations offered by the former. The latter class of contributors —if we except the importers of foreign products, whose interests are identical with those of foreign manufacturers— are unanimous, substantially, in their support of the platform of the Republican party; the former are divided, but mainly arrayed on the opposite side. Salaried men are usually inclined to join the first class; wage-workers are as generally in favor of protection of their own branches of industry. Naturally, every intelligent citizen is inclined to listen to the voice of authority and to admit that the political economists should be allowed to indicate the proper course to be taken in this critical moment; and yet a very large proportion of our most intelligent citizens are disposed to think that the political

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economists who are so nearly unanimous in their support of free-trade views must be in error, and are very much inclined to accuse them of being pure theorists, and of reaching conclusions correct as deductions from their assumed premises, but altogether opposed to the results of experience, and probably to deductions from premises representing actual conditions of life and work. In other words, the pure theory and the applied science of political economy appear to them to lead to quite opposite conclusions, when it is attempted to make them the guides for action in such cases as present themselves to us here and to-day. Every educated man leaves college a "free-trader"; every man entering into business life as a member of the producing or of the commercial classes—those above excepted being here excepted also—at once sees that, somehow, his theories and deductions from economical "axioms" fail of application in practice; and, while admitting often the "theoretical" correctness of the principles which have been instilled by his professors, nevertheless asserts that "practically" the opposite course is right. All protectionists are business men; substantially all anti-protectionists are theorists or of the salaried classes. In this country the two sides are engaging as counsel the professors and college men and the importers and their interested friends as advocates of "free trade," and the manufacturers and dealers and educated wage-workers as advocates of protection to home industries. But why this apparent discrepancy between pure and applied political science?

The case is not without parallel in the history of science. Every science has, at one time or other, illustrated precisely such a discrepancy whenever half-knowledge and half-truths have been accepted as the basis for deduction. It was for this reason that Aristotle failed when he applied his unquestionably correct philosophical methods to physical science, while Euclid succeeded in constructing a correct geometry. Available knowledge was but half-knowledge for Aristotle; Euclid's axioms were all of the case for him. Similarly Ptolemy failed and Copernicus succeeded in finding the true relations and the science of the motions of the solar system; Archimedes failed and Newton succeeded in giving us the basis of dynamics. Alchemy was not a science with the Arabs; chemistry is a science with the followers and successors of Lavoisier. Medicine was no science, but a barbarous method of drug-poisoning, with our fathers; it is becoming a scientific and health-giving, life-preserving system of hygiene in our own time.

Until a generation ago the theory of the steam engine was assumed to be simply a science of transformation of heat into energy of the mechanical form, and, as a consequence of this assumption, the teachings of the writers of authority, of all men of science, of all the schools and text-books, led to the conclusion that it was perfectly practicable to deduce from this pure theory of thermodynamics the actual efficiency of the steam engine; and this conclusion was vigorously defended by the theorists and scholars; and we are even now but just seeing the end of a hot discussion originally initiated between a great authority in thermodynamics and writers of hardly less fame, but whose experience in practical construction and operation of the steam engine has shown them a marvellous discrepancy between the accepted theory of the last generation and the facts of real life. In this discussion the latter have shown a difference amounting to from ten to above fifty per cent. between the results of application of the theory and the actual case. Engineers of practical experience from the time of James Watt, even, had seen this disagreement; and it had had an enormous influence in bringing about that distrust of "theory" and "theorists" which once marked every contact of the two classes of men. The accepted theory of the heat engines, as taught in the schools, was not simply inadequate; it was absolutely false and misleading for all the purposes of the engineer. To-day the theory is becoming modified; the actual conditions of the real case are becoming recognized, and the premises as enunciated are becoming comformable to fact, with the natural consequence that a correct science of the steam engine is being

created, while the results of its application are now becoming accordant with experience; and it is at last found possible to make it of real service in practice in giving us laws controlling design and the management of the engine, in prescribing limitations to be observed in practice. We now, for the first time, have a practically useful applied science of the steam engine, and for the first time find the experience of the worker accordant with the views of the most advanced thinker. Meantime the promulgation of the half-knowledge and the inapplicable science of the older authorities has led to hundreds of attempts to realize the economy indicated as possible by that older theory, and has cost millions of dollars and innumerable disappointments.

So long as it was asserted by the theorist that there existed practically no limit to the gain to be derived by the expansion of steam in the engine, inventors and inexperienced engineers were persistent in their efforts to realize the promised advantage. Failure was inevitable, and must have continued inexplicable had not the comparison of theory with practical results finally led to the discovery that there existed methods of waste of heat in the engine which were inherent in the present system of construction, but were not taken into account in the accepted theory of the machine. *Now* the engineer and the physicist can account for the heat entering the engine unit by unit, and can see precisely where and how it is disposed of, what are the avoidable and what are the unavoidable methods of expenditure and waste, and just in what direction and to what extent further improvement may be sought.

This, in the opinion of many practical men, is a very good lllustration of the method by which the science, so called, of political economy may either mislead, as it has hitherto, the most honest and earnest of its disciples, or may lead us on to correct conclusions and highest prosperity as a nation. The science, as hitherto almost invariably studied and taught, is based on limited and incomplete premises. When it shall have been brought to the condition which is now so well illustrated by the most recent science of the heat engines, its premises and stated primary conditions consonant with actual fact and life, it may be expected that its conclusions will be in full accord with experience; and, further, it may lead us on to a practice that shall be ideal in the sense of being strictly right and of maximum fruitfulness for ourselves, and our neighbors as well.

Were all the world one nation, were all mankind equal in intelligence, enterprise, and ambition, and imbued with equal sense of honor, integrity and Christian love, the assumed conditions of the political economist of the day would probably be not far from right, and we might, perhaps, be safe in adopting his conclusions as a correct policy for all governments. It would then be probably true that, as asserted, every legislative action which in the slightest degree interferes with the natural course of trade and manufactures would do harm to all. It would probably be true that liberty to buy in the cheapest market and to sell in the market of highest price for the vendor would be one which it would be wrong to infringe, either in the case of the individual or of the nation. The greatest good of the greatest number and the best interests of the individual alike would be subserved by absolute freedom in trade. As it is, all the world is in arms, and it becomes the first duty and the highest right of each nation, as of each individual, to make itself safe against forceful aggression. Modern ingenuity, enterprise, and industry, intelligently directed, have brought into close proximity, by rail and by wire, civilized, half-civilized, and barbarous, wealthy and poverty-stricken, thrifty and thriftless, nations; and, as with coin and currencies, the baser will inevitably drive the better to the wall, so will, if permitted, Chinese displace American labor, British products displace Yankee manufactures, and the cheaper labor in every field bring down the higher class to its own level when allowed to compete unrestrictedly. The wars of the sword may possibly be brought to a speedy end by the efforts of intelligent governments and nations; but, as yet, no way has been found to prevent the industrial

warfare which the conditions existing at present—conditions not generally or adequately taken into account by accepted political economy—make apparently unavoidable between the most intelligent, industrious, and wealth-gaining nations and those which stand lower in the scale.

Self-protection and the guarding and encouragement of home industries is thus made the first duty of every nation liable to attack either by the sword or through the channels of trade. If we allow ourselves to be dependent upon a possible enemy for the necessaries of life and of civilization, that fact alone makes war safer for the antagonist, and so much the more probable. If we give employment to the needy people of a distant and improvident or less intelligent community, in the making of articles of necessity, of comfort, or of luxury, rather than to our next-door neighbor, our friend must suffer, and, in most cases, disproportionately, to the gain of the stranger. We must care for our own poor, not for those of Europe, and it is the first duty of every nation to give its work to its own people. If a foreign nation cannot care for its people, it would be hopeless for us to attempt to care for them and for our own poor as well. We may rightly give of our own stores to the needy, as we relieved the famine in Ireland, but not so far as to accept the risk of bringing our own country to the same sad condition. Our duty as a nation is, as is that of the individual, to first make those nearest us safe against suffering, then to work to our best ability for a surplus that we may make good use of it in helping our neighbor.

The constructive arts should be promoted and encouraged and protected in every practicable way. The only practicable way now known to us as at the same time free from annoyance and serious difficulty of application is by the adoption of a "tariff" on imports, carefully adjusted in such manner as to prevent any very large proportion of the products consumed in the country coming from foreign markets, trusting, as experience shows we may safely do, to internal competition to keep cost down to a reasonable limit, such that every man's labor may be expected to supply him with a maximum of return in articles desired by him, giving substantially all our work to our own citizens. If every nation thus cares for its own industries as for its own poor, the maximum welfare of all is assured. Nations unable or incompetent to make their own essential products must exchange or buy at a disadvantage in the markets of more thrifty nations until able to organize and put into productive operation their own systems of manufacture; but the natural and proper state of affairs is that in which each nation is substantially independent of every other for all the necessaries of life, and so many of the comforts and luxuries as it is naturally fitted to produce. The interdependence of one nation or country upon another for the essentials of comfortable life and of national existence is unnatural, and must always be an element of uncertainty and instability. Each nation must, to be safe and prosperous, mainly supply itself with its own provisions, clothing, housing, and education. It may allow the unimpeded action of the laws of trade to control the supply of its inessentials, its coffee, tea, spices, and wines, in so far as they may be better and more profitably imported; but even here, if a new industry can be safely introduced to furnish employment to a surplus of labor, it may be good public policy to establish it at some preliminary cost.

The introduction, support, and encouragement of the productive arts, the constructive industries, is also dictated to every nation by a true system of political economy. It is undoubtedly the fact that were each nation to abjure the now usual policy of protecting its own industries and endeavoring to secure a foothold in the markets of its neighbors, of the world as the phrase goes, and leave, as is now unusual, every industry to the natural operation of the laws of trade, a time might come, wars ceasing, when every industry would find its natural habitat and its best distribution, and the world, as a whole, would attain a condition of maximum prosperity industrially. This condition can, however, be reached in a much quicker

and safer manner by the acceptance by each nation of a system of encouragement of its own industries. Non-interference with the natural course of trade would lead to a final and natural adjustment of highest efficiency; but, as when we seek maximum fruitfulness of our fields, we do not wait for the external cycles to roll around and the reconstitution of the soil by the growth and decay of wild vegetation and the decomposition, by ages of exposure, of the rocks to give us a soil, but apply artificial stimulation in the form of fertilizers and sometimes costly systems of irrigation, so it is that the highest intelligence of civilized nations may be properly directed to the artificial acceleration of the processes of growth of industries. It is no more contrary to natural and moral economical law to artificially stimulate a natural growth of desirable industries than to thus promote the productiveness of our fields.

The most perfect system is that which at once promotes growth and secures permanence of productiveness. Such a system must inevitably, explicitly or implicitly, involve some method of protection, and those who pin their faith upon an obsolete theory and oppose modern methods of protection are very like the working-people of the last century who inveighed against the introduction of machinery and mobbed the inventor and broke up his invention, attacking the best friends of the people that intelligence had ever produced; or are like the more intelligent, perhaps, but unthinking, nevertheless, among our contemporaries who, admitting the value of machinery, with hardly less blindness, would destroy the mainspring of the whole system, the capitalist; attributing to his action all the evils that really come of still incomplete and inefficient distribution of labor and industries.

The most correct and broadest principles of true economics justify and prescribe the application of all the intelligence and power of the nation to the promotion of the material prosperity of its own people, and it is only where material prosperity is assured that advances in morals and intellectual growth are best insured. The prosperity of any nation is the product of its own industry, intelligence, and wisdom, of its own integrity, frugality, and self-government. Other things being equal, that nation is most prosperous and happy which has the largest number of skillful workers, the most diversified industries, and the grandest system of invention applied to the mechanic arts. The primary conditions of success, with the nation as with the individual, are internal, not external. External relations are important, mainly as determining to what extent the internal qualifications for success may be given best play. Diversified and well-intermingled industries are prime requisites of highest prosperity. The best results are, on the whole, reached when each man's labor will give him maximum returns as measured by him in, not money, but the essentials of healthful and happy existence. That country in which the labor of the people is assisted most effectively by the genius of the inventor in turning the great forces of nature into channels through which they shall most effectively aid him in the production of all things needed to supply his demands, and in which, thus aided, the populace, working steadily and intelligently and healthfully, can produce the greatest amount and variety of articles that can be used by the people, is the most prosperous, and should be the most happy. But it is only intelligent and educated peoples that can find use for more than the necessaries of life, and can thus give employment to a maximum number of skilled workers and to fine machinery, operated by trained and skillful men.

Again, a barbarian may sometimes compete successfully with an educated man for employment, if he is trained to do a single thing, to conduct a single simple operation, even in the management of machinery. Hence, that nation which most effectively promotes the introduction of new industries and most thoroughly protects the older and more essential, while at the same time securing its people from the destructive competition, in the great mass of simpler production, of ruder peoples, is certain, in the end, to do most for itself, and soonest to secure a position from which it can do most to promote the welfare of less

fortunate nations. To be more explicit: if we distribute centers of manufactures and bodies of working-people capable of consuming farm products among our agriculturists, the latter at once secure a better market for their products and a more reliable and permanent market, while the former find the cost of subsistence also reduced in an important degree. The contact of the farming classes with the denizens of cities also leads to their gradual assumption of more cultivated methods of life and all the wants that come with increasing culture, and thus lead to the introduction of new industries and the employment in skilled trades and occupations of those who would otherwise compete with themselves for the more common employments. Each class helps the other, and the more thoroughly the industries are diversified, and the more completely they are intermingled, the better the result for all.

Every process and every circumstance which introduces a new want and stimulates a new and higher demand, whether of comfort or luxury, always provided expenditure does not exceed a prudent amount for each, leads to a real improvement in the condition of the people. But the best method of introducing, of stimulating, of making permanent, desirable forms of industry is by the careful protection of infant industries against the competition of outside workers in the same field. The older industry of a foreign nation has enormous advantages over the new-born industry at home, and, in the face of established foreign manufactures, it would seldom be possible to inaugurate similar industries at home. Once established by such protecting and fostering legislation as may be found necessary, protection must be adhered to as a policy until the firm establishment of the business has occurred, and also until internal competition had brought down the cost of production to such a point that the protective bar may be raised. This may, in some cases, mean that a permanent protection must be provided to make permanent some important industry; but this is simply another mode of stating the fact that we must always, in such instances, be prepared to pay something for the advantages secured to our own people.

The real problem, therefore, of the political economist, of the statesman, of the citizen, is to find methods and means of securing the most thorough establishment and most complete intermingling and most extended diversification of domestic industries. That great thinker, John Stuart Mill, has said most truly, "The only case in which, on mere principles of political economy, protecting duties can be feasible is where they are imposed temporarily (especially in a young and rising nation) in hopes of naturalizing a foreign industry, in itself perfectly suitable to the circumstances of the country. He adds, "But the protection should be confined to cases in which there is good ground for assurance that the industry which it fosters will be able after a time to dispense with it." This is undoubtedly the rule; but no nation can ever afford to leave its essential industries at the mercy of foreign competition, until the advantage is at least fairly balanced. The natural and wise method of holding the protection is to keep it up until it simply, in the natural progress of events, becomes evidently entirely needless, or to so arrange the tariff system that a constant supervision may be kept over all its workings and the rates continually adjusted to the requirements of the day in such manner that large imports may be excluded in times of ordinary normal business operation, thus making the barrier one of such height that abnormal monopoly within the lines, resulting in abnormally high prices, may be at once met by the action of foreign competition and at once held down to the natural and desirable condition of the market.

A properly-constituted commission of wise and statesmanlike men, familiar with the practical working of the tariff and its effect upon the industries and prosperity of the country, advising with Congress and the Executive in the adjustment of tariff and revenue laws and regulations, would be the best assurance of permanent and growing wealth and comfort that the nation could possibly have.

Assuming that the country decides

the pending issue about to be presented in the next Presidential election in favor of "free trade," it may be that the result would, in the end, prove a benefit. That it would cause the partial, perhaps complete, destruction of important industries, and an unimaginable amount of suffering among the people, can hardly be doubted; but the people of this country are quick to learn a lesson taught by such an experience, and we may be sure that once the right course is again resumed, it would be many years, if not decades, before it would be forgotten. Should the people decide to adhere to the system which has proved to be beneficial, and under which such wonders have been wrought, as a permanent policy, and should it continue to hold that policy indefinitely, we may be certain that we shall never lose the position now held by us as the most fortunate and prosperous nation on the globe.

The result, as affecting other nations, would undoubtedly be that each would gradually become itself independent, and when it has reached a sufficiently secure position in respect to its neighbors a "zollverein" would be arranged, by means of which permanent and free interchange of all products could be then safely permitted. We may expect, ere many years, to see our growing neighbor, Canada, entering into such a compact with the United States, Mexico coming into the system later, and one after another of the South American nations, and the West India Islands, until in time the whole continent forms one great industrial union. This is the natural and only desirable method of absorption of neighboring countries by the United States; and no legislation should be permitted to hasten the movement faster than the industrial changes here anticipated may take place, and thus make the aggregation of nations into one great whole safe and desirable. This is the process by which we may anticipate that the ideal conditions of the older political economist and of the free-trader of to-day may be realized. No other method is likely to prove safe or economically advisable. The world will some time, we may hope, become one great "zollverein," and all restrictions of trade and manufactures, now wise and necessary, will then be thrown aside. But wars must first cease and adjacent nations must first bring themselves up to the most advanced standard reached by other countries with which they have commercial relations. The universal zollverein and the millenium will probably both be seen some day, and they may probably come together.

History and experience alike confirm our deductions, as above expressed. Two hundred years ago the government of Great Britian, our principal competitor in industrial contests, asserted her intention to, so far as possible, secure a monopoly of the manufacturing of the world for her own people, *i.e.*, to obtain for her own people a monopoly of employment in the skilled industries, in all those vocations which are best paid. Her first aggression upon the people of America was an attempt to forbid the organization of our infant industries; our first protest was against being compelled to go to the other side of the Atlantic for our manufactured wares. She legislated directly against our interests in this matter when we were a colony and sought by every possible means to secure and retain the privilege of employing her own people rather than ours in all manufacturing vocations after we became independent. She would have compelled us to content ourselves with the pursuit of agriculture and with no other market of importance than that to be found among agriculturists or on the other side of the ocean. Her policy, if successful, would have inevitably prevented our ever attaining any such positon among the nations of the world as we to-day hold; had we failed in our remonstrance and resistance we should probably still be dependent and weak.

The wealth which can only come of such diversification of industries, and of such promotion of the inventive genius of a people as our wise patent laws have produced, is essential to the safety and permanence of our institutions. Without the first, we should have been in a worse position than is Canada to-day; without the second, we could have probably done no better in competition with Great Britain than have, until recently,

the nations of the continent of Europe. Technical education and the importation of British industries, capital, and workmen may now do much for them, and may finally give them that independence that only tariff laws can usually afford.

Our indeterminate and unsettled tariff policy has sometimes given to Great Britain the opportunity she so persistently—and wisely, in view of her own immediate interests—seeks; and each time disaster has followed, and of such extent as such departure from our only safe plan should have been expected to produce. Each time a resumption of the policy inaugurated by the colonists and upheld by Washington, Jefferson, by almost every great statesman since, had saved us from complete ruin. Had we had as many Carys among political economists as we have had Jeffersons among statesmen, few though they would be, we should have been vastly better prepared for this continual struggle than we are to-day. Once a correct platform is settled by the votes of the people, justified by the principles of the applied science of political economy, and so recognized by our educated citizens, and held in force by the will of the people, we shall enter upon a period of prosperity that will be, perhaps, no more satisfactory at its best than now, but certainly far less subject to fluctuations and destructive crises.

Once an applied science of political economy becomes recognized as possible and practical, it will probably be promptly seen that we are as much bound to protect our labor-supply as our industries, to preserve the quality of our citizen-body as that of our manufacturing system. We shall then have wise laws to facilitate the introduction of desirable additions to our population, while at the same time restricting, if not actually stopping, the introduction of the undesirable. We shall welcome the intelligent, the frugal, the industrious classes from other countries; we shall absolutely forbid the immigration of the thriftless, the idle, the ignorant, and the criminal. And it will be by thus promoting, by every known device, the healthy development of the resources and the industries of our country and the growth of right principle and good practice, in all the relations of citizen to citizens, and of citizen to the State, that we shall ultimately, if we act wisely, make this country, more than ever before, the happiest, the most free, the most prosperous on earth.

Could we revive the spirit of patriotism of our grandfathers and of our grandmothers, and could every man and every woman in the land be brought to appreciate the privileges of a free and prosperous country, we might not find it necessary to urge upon our own fellow-citizens the arguments of personal interest or the abstract principles of correct political economy. The spirit which converted Boston harbor into a teapot, and led our ancestors to prefer the products of the American loom and mill to those of foreign establishments, which was ready to fight with the most powerful nation of the time rather than yield the privilege of making our own iron and steel, and cloth and machinery, would to-day lead every patriot to do his part, even at some sacrifice, were it necessary, to preserve existing manufactures, and to introduce and cherish new branches of industry, in order that our own people should secure such remunerative employment and gain in wealth, and especially in independence, as is only possible when we are able to ourselves produce all that we need, and at greatest advantage.

Said Daniel Webster, "That is the truest American policy which shall most usefully employ American capital and American labor, and best sustain the whole population"; said Andrew Jackson, "Upon the success of our manufactures, as the handmaid of agriculture and commerce, depends in a great measure the independence of our country"; said Thomas Jefferson, "Experience has taught me that manufactures are now as necessary to our independence as to our comfort." Every man who loves his country, and sincerely desires for her the highest possible prosperity, will, in the present crisis, exhibit the same spirit, and that feeling which animated our forefathers a century ago will now again lead our people to act promptly and vigorously to preserve that independence which was then won.

STEAM BOILER EXPLOSIONS.*

By J. M. Allen, President Hartford Steam Boiler Inspection and Insurance Company.

IT was my privilege nearly one year ago to speak in this hall on the subject of steam boilers, their construction and management, with a view to safety and economy.

The importance of proper construction and management is forced upon us almost daily by the accounts of steam boiler explosions, often attended with great loss of property and life. During the six years ending January 1, 1886, there were 992 boiler explosions in this country by which more than 1500 persons were killed, and many more injured. A large amount of property was destroyed and damaged, beside the loss resulting from delays in rebuilding and replacing boilers and machinery destroyed or rendered useless. These figures are taken from a record which has been kept for many years in the office of the company with which I am connected. They are gathered through our agents in all parts of the country, also from the daily papers. The list may not contain every case of a ruptured or exploded boiler, but it is perhaps as near correct as any such list could be made. The loss or damage to the owners of these mills or works can be only roughly estimated. In some cases it has amounted to $10,000 and even $20,000, while in others it would be covered by a few hundred dollars.

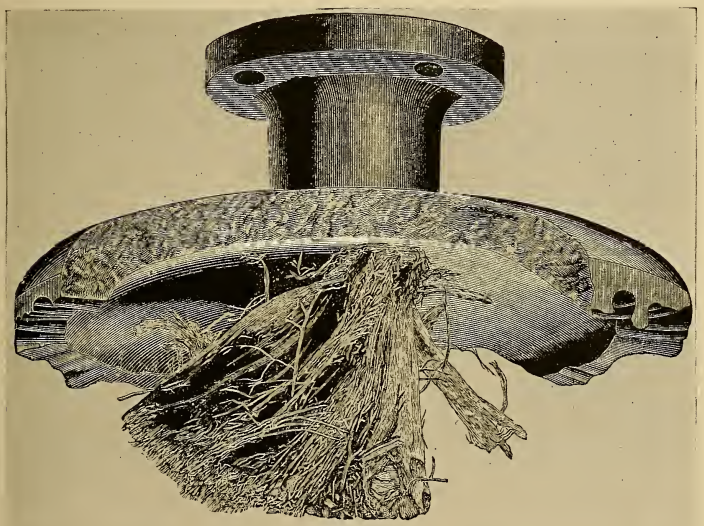


FIG. 1.

FIG. 1.—A PINE PLUG AFTER THE EXPLOSION.

If we assume an average of $3000 in each case, it gives a grand total of about $3,000,000. These facts are of sufficient

*A lecture delivered at Sibley College, Cornell University.

importance to lead to earnest inquiry and investigation into the cause of these frightful accidents. The importance of such investigations was recognized more than fifty years ago. The whole subject was shrouded in mystery, and some of the theories put forth were laughable. One of the earliest was that all boilers were exploded by electricity. This theory is said to have become popular in this country more than fifty years ago, from the explosion of a locomotive on the boilers. Before speaking of the experiments of the Franklin Institute, I will say a word about the theory of explosions from electricity. Some forty years ago, in England, a locomotive at rest was found to emit brilliant sparks while the safety-valve was blowing. This was thought by some to be conclusive evidence that electricity was stored up in a boiler under pressure, and that, under certain conditions, it might act with explosive results. This led to a

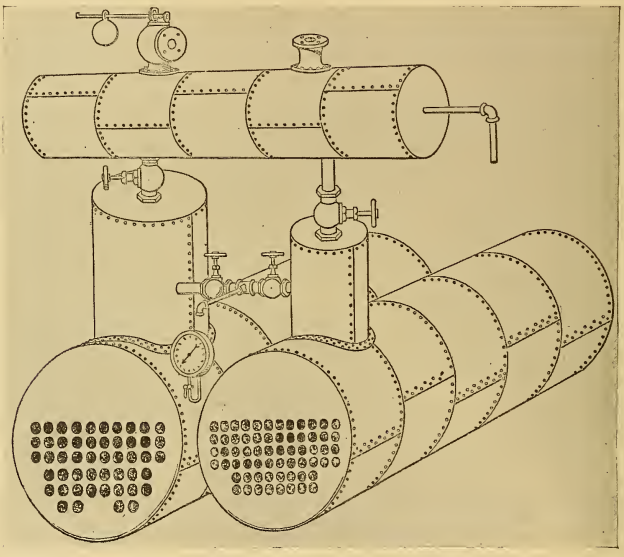


FIG. 2.—SHOWING IMPROPER ARRANGEMENT OF SAFETY-VALVES.

Baltimore & Ohio Railroad during a thunderstorm. It was asserted that it was struck by lightning. Subsequently, another exploded on a clear day, but as the subject of boiler explosions had at that time been little studied, and as there seemed to be no ready explanation, it was assigned to the same cause. About this time, at the request of the Treasury Department of the United States, the Franklin Institute, of Philadelphia, instituted a series of experiments to test the truth or falsity of the various causes assigned for the explosion of steam careful investigation of the subject by men of high scientific attainments. The result was that the presence of electricity in a jet of steam issuing from an orifice was not due to free electricity within the boiler, but to the friction of the escaping steam upon the inner surfaces of the discharging channel.

If electricity should be developed in a steam boiler by ebullition, or in steam when confined under pressure in an iron boiler in perfect electric communication with the earth, it could not be collected, but would be immediately conveyed

away. Professor Faraday investigated this matter, and his conclusions were :

1. "The production of electricity is not due to any change in the state of the liquid contained in the boiler.

2. "A current of dry steam produces no development of electricity. The production of electricity is due to the friction in the nozzle of the drops of water formed by the partial condensation of the steam.

3. "Increasing the pressure of the steam increased the development of electricity by increasing the friction of the issuing jets of steam and water.

4. "The same results were obtained from compressed air, discharged through the boxwood nozzles, as from steam discharged under the same circumstances. When the air was perfectly dry, there was no development of electricity ; when the air was humid, and contained, besides, a very little pulverulent matter, the friction of discharge produced electricity in the same manner as when steam was employed in the experiments."

The boiler which was used in these experiments was insulated on glass supports or legs, and yet the experiments under these most favorable conditions conclusively show that electricity could not be counted among the causes of boiler explosions.

To return to the experiments of the Franklin Institute. Among the causes of boiler explosions to be investigated were the following : 1. That injecting water into a boiler in which there was no water, but only hot, unsaturated steam. This would be a case of extreme "low water" or no water at all. The theory was, that when water was thus injected into a boiler containing hot and unsaturated steam, the water would immediately flash into steam of lower temperature, but of sufficient pressure to rend the boiler in pieces. Without going through with this experiment in detail, I will simply give their conclusions, which are as follows :*

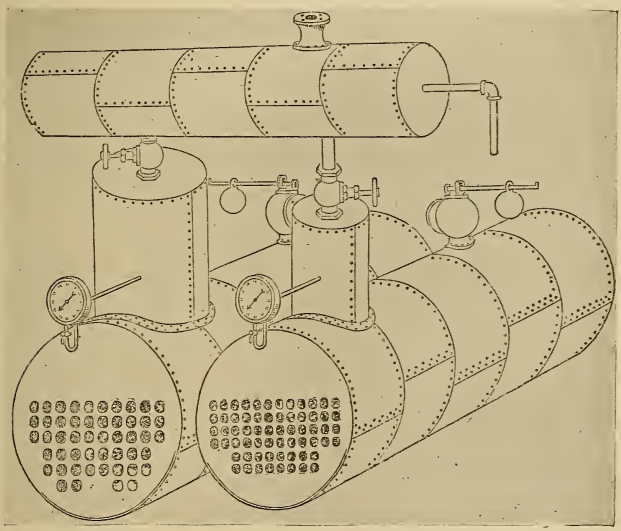


FIG. 3.—SHOWING PROPER ARRANGEMENT OF SAFETY-VALVES.

"We see that in no case was an increase of elasticity produced by inject-

*See *Journal Franklin Inst.*, vol. for 1836.

ing water into hot and unsaturated steam, but the reverse; and in general that the greater the quantity of water thus introduced, the more considerable was the diminution in the elasticity of the steam." There is a very prevalent opinion that injecting water into a hot boiler in which the water has been allowed to get very low is a fruitful cause of boiler explosions.

This is called the "low-water theory." It is maintained that the water, coming in contact with the hot plates, suddenly flashes into steam of great pressure. Assuming that the severe overheating of the plates has taken place, and water is suddenly thrown upon them, there is reason to believe from the foregoing that the steam disengaged would not be sufficient to greatly increase the pressure already in the boiler. We know that plunging a mass of red-hot iron into three or four times its weight of cold water disengages comparatively little steam, and there is no good reason for believing that any more steam would be disengaged if the iron were disposed of in the form of a boiler, and heated to the same temperature. But there are other arguments against this theory. If I remember correctly, a government commission was appointed in 1873 to make some experiments with a view to ascertain the cause of boiler explosions. Among those experiments was one bearing upon this theory. They injected water into an overheated or hot boiler. The result was, contorted plates, leaky seams, and a general demoralization of the boiler, but no explosion.† It must not be inferred from this that no damage arises to a boiler that has been overheated from low water, nor that after such an experience a boiler is suitable for use. On the contrary, it may have been so strained and weakened as to be totally unfit for use at any pressure. I have no doubt that this has been the indirect cause of many boiler explosions. The engineer or fireman allows the water to get low—very low; the plates are overheated and weakened, the strength of the iron is greatly reduced, but instead of drawing the fires and ascertaining what damage is done, he immediately starts the pump, and thinks to cover his carelessness by filling the boiler with water. His fires are urged to keep up steam, but the boiler has been so weakened that it is utterly unable to sustain the pressure, and it "gives out," or "lets go," with more or less destructive results. Another cause which had many advocates was investigated by this Franklin Institute Commission, namely: "decomposed steam." This is often called the "gas theory." It is this: The steam coming in contact with hot iron is decomposed, that is, the hydrogen is set free, which, uniting with a certain portion of oxygen, forms an explosive gas, which is sufficent to account for many of the destructive explosions.

The experiments of the commission extended over several days, and in one or two instances they succeeded in producing a combustible gas. But other experiments proved that this result was due to the packing of the hand-holes at each end of the experimental boiler. This packing, consisting of cloth and putty, was highly heated, and the cloth mainly disappeared. They further showed, at least satisfied themselves, that when the bottom of the boiler was heated to redness, no hydrogen was liberated by the decomposition of the water injected. Their conclusions were that "water in contact with heated iron in a steam boiler, the surface being in its ordinary state, clean, but not bright, is not decomposed by the metal."

At a meeting of the American Academy of Sciences, in 1877, it was shown that steam could be decomposed by simple heat into the constituent gases of water, viz: hydrogen and oxygen. The apparatus consisted of a flask in which water was heated, a tube conveying the steam to a closed platinum crucible, where it was again heated by a spirit lamp, and a tube which carried thence the superheated steam and the liberated gases to an ordinary pneumatic trough, where the mixed gases were collected in

† Professor Thurston informs me that the commission that made the experiments at Sandy Hook did succeed in exploding a boiler by injecting water into it when the plates were red hot. But very little energy was developed, and it could not be considered as among the causes of destructive boiler explosions. See *Scientific American*, 1875.

a test tube while the steam was absorbed. The gases thus collected were exploded by a lighted match. But the question arises, Could this or a similar condition of things take place in a steam boiler? In order to produce an explosive gas in a steam boiler, a large portion of the plates inclosing the steam space must be raised to a bright red heat, then the steam must be condensed by the injection of cold water, which must not come in contact with the red-hot plates, for if the plates are cooled down, how is the explosive gas to be ignited? These conditions are hardly supposable in a steam boiler.

The injection of feed-water into a red-hot boiler would weaken the plates and joints and very likely produce rupture. This theory has few advocates now among those who have made the subject a study. The opinions of Professors Faraday, Taylor, and Brande go to show that the cause of boiler explosions by the decomposition of steam is without any support whatever. Another theory, which has some advocates, is that known as the de-aerated and superheated water theory. It is sometimes known as the Donny theory, because advanced by M. Donny, in 1770. It is this: That water completely deprived of air may be raised to a very high temperature without ebullition, and that under these conditions it has explosive tendencies.

Superheated water would be water heated above the boiling-point, due to the pressure on the water at the time, without giving off vapor. If this were possible in a steam boiler, it would be a source of great danger. Many persons have attributed violent and destructive steam boiler explosions to this cause. But we have no evidence whatever that these conditions ever exist in a boiler. The conditions absolutely necessary for the production of superheated water, according to the experiments of Professor Donny, were: "No portion of the surface of the water can be exposed to the atmosphere or any other vapor or gas." Again, the contact of a solid body or the smallest particle of air or gas is fatal to the success of the experiment; and again, if steam once begins to form, it goes on and cannot be stopped until the water is all evaporated. These con-

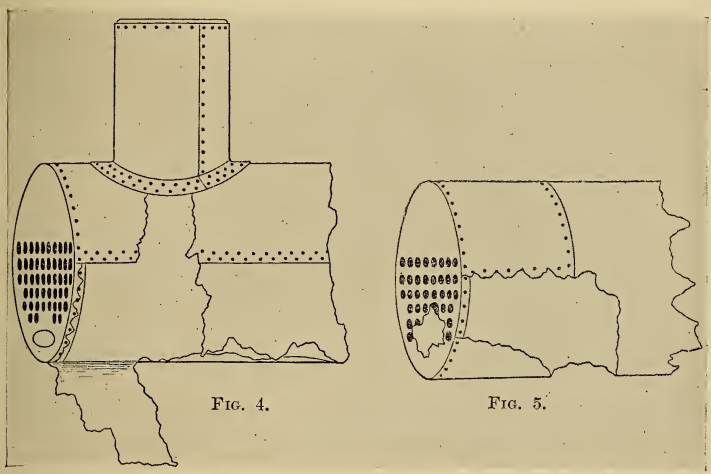


FIG. 4.

FIG. 5.

FIGS. 4 AND 5.—BOILERS SHOWN IN FIG. 2 AFTER THE EXPLOSION.

ditions could not exist in a steam boiler. The experiments of Mr. A. Guthrie, formerly United States Supervising Inspector of Steam Boilers, were conclusive in showing that this theory had little or no foundation as a cause of boiler explosions. The results of his experiments were published originally in the *American Artisan*, and can be found in the August *Locomotive*, 1882. I have spent some time in telling you what, in my judgment, are not causes of boiler explosions, and you are no doubt impatient to learn by this time what are some of the causes of these frightful accidents.

A well-constructed steam boiler of good material cannot be exploded except by great force. Knowing the quality of the material, the type of boiler, and assuming that it is well constructed, we can easily calculate the force or pressure of steam which it is capable of resisting, and the pressure which would burst such a boiler asunder would be much higher than any pressure which would ever be allowed on such a boiler under the ordinary conditions of use. A boiler explosion under such circumstances would be called an explosion from over-pressure, and such accidents do not occur except from carelessness or oversight in their management. A stop-valve may be closed or the safety-valve may be inoperative from corrosion or other cause, rendering relief impossible.

The following illustrated cases will show that through carelessness a boiler may be exploded by over-pressure. In a Southern city the fire-sheets of a boiler became weakened, and repairs were necessary. The boiler was connected with another boiler, but a stop-valve in the main steam pipe between this boiler and its companion allowed it to be shut off and put out of use for repairs. The boiler was 48 inches in diameter and 31 feet long, with two flues, each 16 inches in diameter and 27 feet long. Each boiler was provided with a safety-valve attached to the nozzle on cast-iron head of dome. The main steam pipe was also connected with this nozzle. While the men making the repairs were at work in the boiler, hot water from the condensed steam that leaked through the stop-valve trickled down upon them and greatly annoyed them. To prevent this, one of the men made a pine plug to fit the hole in the nozzle, and drove it in from the inside. When the repairs were completed, the men gathered up their tools and got out of the boiler, entirely forgetting the pine plug. The manhole was put in place, the boiler filled to proper height with water, and the fire started. The boiler is said to have behaved very strangely. No steam could be raised. But after an hour or two the top of the dome was raised several hundred feet, and was found a long distance away the following day. Fig. 1 gives a correct view of it when it was found.

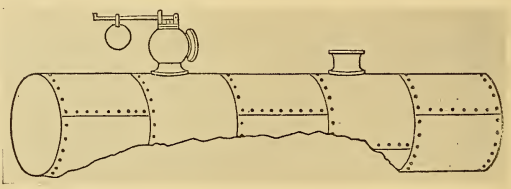


FIG. 6.—BOILER SHOWN IN FIG. 2 AFTER THE EXPLOSION.

This was a case of explosion from over-pressure. The boiler was abundantly strong for the ordinary pressure required, but the only outlet for the steam was securely closed, and the safety-valve rendered useless. Another case of explosion from over-pressure occurred in a Western town. There were two boilers set and connected together as shown in Fig. 2.

It will be seen that there are stop-valves between the domes and the steam drum, on which the safety-valve for the two

boilers was located. This arrangement was made so that one or both boilers could be used. The owner was warned of the danger of such an arrangement, and advised to put a safety-valve on each of the boilers, as shown in Fig. 3.

But he neglected to do so. And one day, after shutting off one boiler, he built a fire under it, forgetting to open the stop-valve. There being no escape for the accumulating steam, the boiler was blown in pieces, as shown by Figs. 4, 5, and 6. There are no doubt many explosions from over-pressure through carelessness, similar to these cases.

Mr. Fairbairn was of the opinion that all boilers exploded from over-pressure, that is, that the pressure used or allowed was greater than the ability of the boiler to withstand. The element of carelessness entered into his calculations, but his opinion was that no boiler exploded except from excessive pressure. His experiments were made many years ago, since which time the use of steam power has vastly increased, and with its increase boiler explosions have increased as well. We have indisputable evidence that boilers, even those which appear to be good boilers, explode with great violence at ordinary pressures and at comparatively low pressures. When we examine the fragments of such exploded boilers, we rarely fail to find some hidden weakness from corrosion or from some defect in material or construction. The careless use of the drift-pin in the construction of boilers has no doubt been the cause of many accidents. I have been in boiler-shops where this instrument was wickedly used. The rivet-holes failing to come fair when plates were brought together, one riding over the other, the drift-pin was used to so adjust them that a rivet could be inserted. The drift-pin, under the blows of an 8- or 10-pound sledge-hammer, with a handle four feet long, causes great distress of the material, and if it does not fracture under the treatment, it is fair to assume that a strain is brought to bear which under ordinary steam pressure will be aggravated, until from weakness and utter inability to "hold on" longer, rupture occurs.

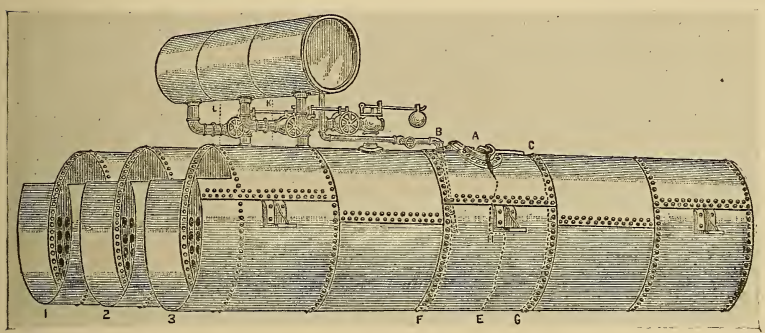


FIG. 7.—BOILERS WHICH EXPLODED. CAUSED BY RUPTURED MANHOLE FRAME.

Showing the relative position of the boilers 2 and 3, the two that exploded, breaking first at the manhole of No. 3. B F, A E, and C G, secondary lines of rupture. K L, dotted lines showing location of brick piers built for the support of the steam drum, upon the mid walls of the setting.

Another case of explosion from carelessness is illustrated by the annexed figures.

Fig. 7 shows the boilers as they appeared just before the explosion. The boilers were nearly new, each 54 inches in diameter and 17 feet long. After using them for some months, some changes were made in the steam drum connections, which being completed the boilers were put in use. The manhole plate of one did not fit tightly; probably from some small portions of the old gas-

ket adhering to the seat. Steam issued from the joint, and instead of waiting until the work of the day was over, so that the cause of the leak could be ascertained, two men secured a wrench with a long handle, and endeavored to force the manhole plate on to its seat by screwing down the nut of the bolt that held it in place. They were not successful in stopping the steam leak. So a long piece of pipe was secured and slipped over the handle of the wrench, and with this increased leverage these two men exerted their whole force to bring the manhole plate into place. The frame of the manhole, which was cast-iron and sufficiently strong for the purpose intended, was fractured by this careless and violent usage. The rupture extended into the sheet, and a very destructive explosion followed. The pressure of steam on the boilers at the time was about 80 pounds. This shows how important it is to secure men of intelligence and good sense to properly care for boilers under steam.

Another defect is grooving, which arises from a channeling of the plate. This is caused by some strain, generally brought to bear from the uneasy resting of the boiler in its setting. It may arise from strains caused in construction. But it generally appears along the edge of the lap of both horizontal and girth seams. The continued bending back and forth of the metal loosens up the fiber, and opens it to the attack of any impurities that may be in the water. The channels of grooves extend sometimes nearly through the plate; fracture occurs, and disaster is very liable to follow. A boiler originally well constructed and strong may become weak from low water—I mean by this, overheating from low water—and be in a condition inviting rupture or explosion when used under ordinary working steam pressure. The deposits from bad boiler water work great mischief. Their accumulation in the form of scale of greater or less thickness on the plates of boilers is a source of much trouble and danger. Plates become overheated and burned, and have little ability left to withstand the pressure within. These are some of the conditions attending the use of boilers; and when I remember how many of these cases there are, the wonder is that more boilers do not rupture and explode. In a horizontal tubular boiler 60 inches in diameter and 16 feet long, ready for use, there would be 1135.91 gallons, or 9465.8 pounds of water. When we start the fires under the boiler, the heat is communicated to the water, which rises in temperature until at 212° Fahr. it begins to emit steam from its surface. The steam, however, is formed at the heating surface of the boiler, and forces its way up through the water to its surface. As the fires are continued, this process goes on with great energy, and violent ebullition is the result. If there is no outlet for the steam thus generated and the safety-valve is weighted to say 80 pounds, the steam will accumulate in the steam room above the surface of the water, until it reaches a pressure of 80 pounds to the square inch, when it will begin to issue from the safety-valve. The temperature of the steam and water at this pressure is 324° Fahr., or 112° above the temperature of steam at atmospheric pressure. The velocity of discharge of steam at this pressure is about 1450 feet per second, or at the rate of 16 miles a minute, or 960 miles an hour. The pounds of steam discharged per minute per square inch of opening at this pressure would be about 82 pounds, which multiplied by 4.56, the volume of one pound of steam at 80 pounds pressure, will give us 373.92 cubic feet. I give these figures in order to give some adequate idea of the velocity of steam under pressure of 80 pounds. At 100 pounds pressure, its actual velocity of efflux would be not less than 1600 feet per second. But from investigation we have good grounds for believing that steam alone at this pressure would not be sufficient to cause a disastrous explosion, even if the rupture were to occur. Steam cylinders of engines sometimes fail. The steam is nearly at boiler pressure, and the cylinder is usually of cast-iron, but the pieces are not thrown violently away. The pressure is immediately released and its force is gone. We must look, then, for some other cause than steam alone for destructive boiler explosions.

To refer again to the boiler with a

steam pressure of 80 pounds, what are the conditions? We have a boiler 60 inches in diameter under 80 pounds pressure of steam. The quantity of water is 168.17 cubic feet, or 1135.91 gallons, or 9465.8 pounds. This water is heated up to a temperature due to the pressure of steam, or 324° Fahr. All this contained heat in excess of 212° is ready to flash into steam if it had the opportunity, but the superincumbent pressure of steam on the surface of the water holds it in subjection, as a reservoir of power from which to draw as the steam above is used. If we now suppose a rupture to occur above or near the water-line, the steam already

Sandy Hook in 1871, Professor R. H. Thurston presented the following calculations of the energy stored up in the boiler and of the work done by the liberated forces. The steam boiler referred to weighed 40,000 pounds, and contained about 30,000 pounds of water and 150 pounds of steam in the steam space, all of which had a temperature of 301° Fahr., when, at the moment before the explosion, the steam pressure was 53½ pounds above that of the atmosphere. Professor Thurston says, "When the explosion took place, the whole mass at once liberated its heat until it had cooled down to the temperature of vapor under

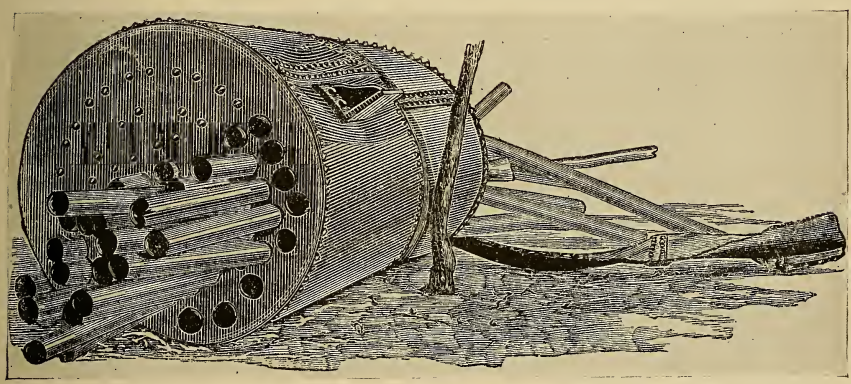


FIG. 8.—REAR VIEW OF THE PART OF NO. 3 BOILER SHOWN IN FIG. 7.

formed would rush out at a velocity, at first, of at least 1450 feet per second. The steam space of the boiler would be nearly emptied before the heat contained in the water could so far overcome the inertia of the water as to disengage additional steam. The steam which would rise from the water, carrying a great quantity of water with it, would strike with great velocity upon the upper part of the boiler, and in my judgment be sufficient to rend the boiler in pieces and project the broken parts to a great distance. I have always found that the most destructive boiler explosions were those where there was evidence of the usual supply of water. In discussing one of the experiments at

the pressure of the atmosphere." I will not follow Professor Thurston's calculations through, but he concludes that the maximum possible effect of these liberated forces was sufficient, had it acted in one direction, to have thrown the boiler more than five miles high. As it was, with the liberated forces acting in all directions, portions of the boiler were projected from 200 to 400 feet high. You can find this discussion in full in the *Journal of the Franklin Institute* for March, 1872.* I quote this with great

*See Transactions American Society Mechanical Engineers, 1884, and *Journal of the Franklin Institute*, December, 1884, for Professor Thurston's latest paper on this subject, giving the amount of this stored energy.

satisfaction because it so fully corroborates the views which I have always maintained from the examination of many boilers which have exploded under the conditions common to boilers in use. The question now arises, Why do not all boilers that rupture explode with such violence? It depends on the locality of the rupture, and its dimensions. If a crack or fracture occurs on the bottom of a boiler and does not extend to any great length, the water will run out no faster than the steam is liberated into the steam space; but a large rupture at or near the bottom of the boiler, sufficiently large to suddenly discharge a large quantity of water, would be followed alike with destructive results. For by this great disturbance in the steam space of the boiler the disengaging steam from the water, together with the water, would act upon the shell with great force and destructive results.

Another cause of boiler explosions is the effort to connect boilers under different pressures of steam by opening the stop-valve between them. The water races from the boiler of higher pressure to that of lower pressure with a velocity and force due to the difference of pressure and volume of water so disturbed. Very destructive explosions have resulted from carelessness of this nature. I desire now to call your attention to a case that is of special interest as bearing upon the many theories of boiler explosions which have been advanced from time to time. The drawing (Fig. 10) illustrates the explosion of a rotary bleacher, such as are used in paper-mills. It was 20 feet long and about 5 feet in diameter. The plate ruptured at the manhole or stock-door, and instead of quietly dropping its load,

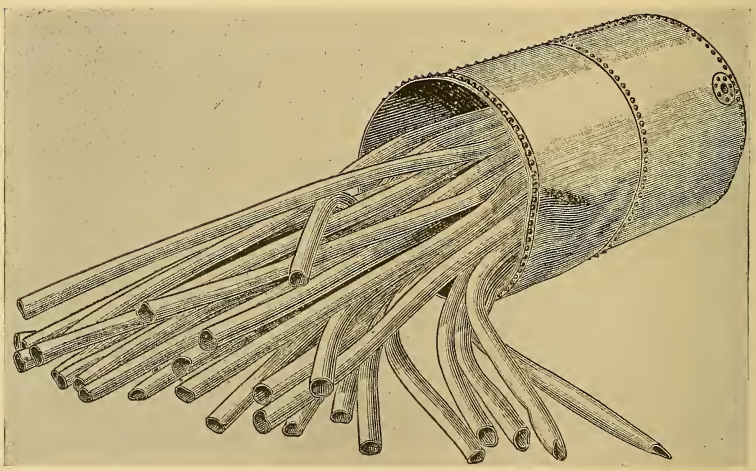


FIG. 9.—AN EXPLODED BOILER.

it exploded with great force, entirely demolishing the mill and causing great destruction to life and property. This vessel was 150 feet from the boiler which supplied it with steam. There was no fire near it, and no heat save that due to the pressure of steam which supplied it. The pressure of steam was about 50 pounds. Here we have a case which will be difficult of explanation by any of the "mysterious-agency" theories. It certainly was not electricity nor de-aerated water. There were no overheated plates, hence no place for decomposed steam. But there was an explosion that caused fearful destruction. The heat in

this large amount of water became destructively energetic as soon as an opportunity was given it to act. What weakness might have existed in the material I am unable to say, but there was a rupture sufficiently large to change its potential energies into terribly destructive activities. I will add that up to this time we have the record of some 30 explosions of similar vessels. They are always destructive, because the contained water at a high temperature is a reservoir of power which nothing can resist when it is once liberated. Is there

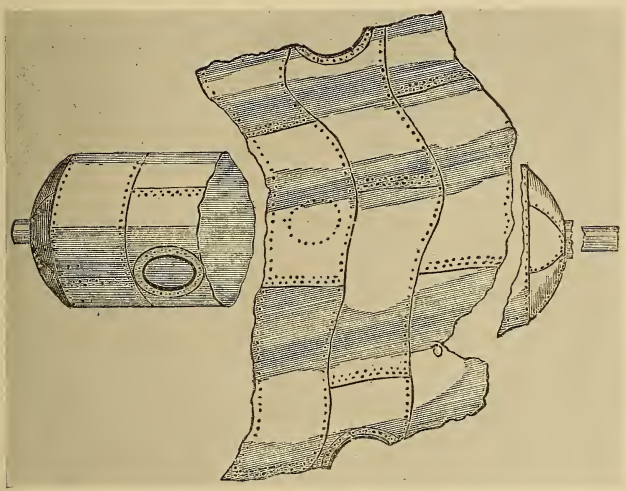


FIG. 10.—EXPLODED ROTARY BLEACHER IN A PAPER-MILL.

any remedy for these terrible accidents? Yes, within certain limits. I say within certain limits, because certain conditions are involved, and first, if the material of which the boiler is constructed is of inferior quality, it can never be considered as safe at the pressures at which boilers in these days are used. A difference of a cent or a cent and a-half per pound in the material often decides as to what material shall be used; for the boiler must be built for a certain price. Thus very inferior material often finds its way into boilers. Then there are defects in construction. The drift-pin is wickedly used. The work is not properly laid out, and undue strains are brought to bear in different parts of the boiler, which are greatly aggravated when the boiler is subjected to the conditions of use. These defects cannot be detected by visual examination. The boiler is subjected to a cold-water test 50 per cent. greater than the pressure required when the boiler is to be put in use. It shows no leaks. But this does not reveal any of the defects which may exist, and which could only be detected by cutting the boiler in pieces.

Another source of danger is the tendency to employ cheap and ignorant men to have the care of boilers. Some steam users utterly fail to comprehend the responsible position of an engineer who has charge of the steam plant of a large mill. Some of the cases of explosions which I have cited go to show the ignorance and carelessness of men who are intrusted with these responsible duties, and in this connection I desire to say a word for the competent stationary engineer.

He stands constantly before his engines and boilers day after day, watching

with care every detail, and upon his efficiency depends to a certain extent the successful operation of the whole plant. The economical use of fuel is in a great measure in his hands, provided the boilers are properly constructed, set, and connected. It is economy to employ intelligent men for such responsible duties, and pay them adequately for it. There has been of late an effort made on the part of stationary engineers to organize themselves into associations for the purpose of mutual improvement. It is a movement in the right direction, and so long as such associations are kept free from politics and other disturbing influences, they should be encouraged. Another means by which boiler explosions can be greatly reduced in number is by thorough inspections. These will not prevent carelessness nor some of the causes which lead to boiler explosions. As I have already said, it is next to impossible to detect the inferior quality of the material when once the boiler is completed and set. But a careful inspection does detect the defects and weakness of such a boiler after it has been put in use, and I have no hesitation in saying that many very destructive explosions have been prevented by careful inspections. To sum up, then, I will repeat what I have often said. Boiler explosions are mainly due to inferior quality of material, faults in type, poor construction, and ignorance and carelessness in management. We must be honest in whatever we do. Money-making is the ambition of all or nearly all, but if it is made at the expense of honesty it brings little comfort. A person once detected in a dishonest trick will find it difficult to gain the confidence of the public afterward.

THE LONGEST IRON SHAVING AGAIN.

THE long shavings that were mentioned in the December number of this magazine must give way for one which was turned at Greenbush (now East Albany), N. Y., in the summer of either 1877 or 1878, at the Boston and Albany shops at that place.

Mr. Thomas Purves was master mechanic at the time, and the shaving came from one of the driving-wheels of the engine "Palmer," a 5-foot wheel engine, with a tire made by the Washburn & Moen Company, of Worcester, Mass.

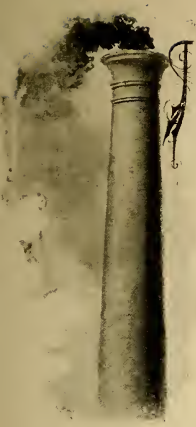
The shaving was, we have been informed, 684 feet in length, and was of about 1 inch in diameter, making the shaving, if uncurled, a little over three times the length given. This shaving was for a long time preserved by the Washburn & Moen Company, as a memento of the occasion, to show the quality of steel in the tire.

ELECTRICITY IN OYSTER CULTURE.

IT might be thought that electricity would be about the last adjunct to employ in studying the culture of the succulent bivalve. An application of it, however, according to the *Electrical Review*, of London, has recently been made by Mons. Lacase-Duthier, the well-known authority on oyster culture. He makes use of the electric light in examining the stages of development through which the spawn passes. A glass cylinder is mounted in a cylindrical skeleton cage which serves as a support; into this glass the water containing the spawn is placed. At the bottom is a plane, silvered reflector; the cover forms a parabolic reflector in the center of which is fixed a small incandescent lamp. The reflectors and the sides of the glass cylinder act in such a way that but few rays of light emerge from the apparatus directly, hence the liquid is suffused with a soft illumination which is admirably suited to the examination of the contents. This little apparatus, or a modification of it, is now being employed in various researches into the life processes of ferments and the culture of microbes, illumination by incandescent electric lights being much more suitable for the study of these low forms of life than that from other artificial sources.

SOME PREVENTABLE WASTES OF HEAT.

By William Kent, M.E.



HAT "Waste makes want," and "Saving of waste makes wealth," are two maxims which should be remembered by every user of coal. Nearly everyone is interested in saving coal: the manufacturer, to save loss or to increase his profits; the consumer of manufactured goods, in the cheapening of their price; the nation at large, in the increase of wealth. Even the miner of coal may be interested in its saving, for no amount of possible saving of coal will equal in any one year the national increase of coal consumption due to increase of population, and increase of national wealth. The more saving made, the more wealth grows, the more manufactured goods are wanted, and the greater demand for coal. So the saving of coal does not throw the poor miner out of employment, or make less coal for the railroads to carry, or less to be handled by the teamsters or others who handle it after it leaves the railroads.

Waste of coal may begin in the coal-pile itself, or in the handling of it, by its crushing into dust, which may be lost. Some varieties lose some of their heating power by the influence of the atmosphere,—bituminous coal mainly,—anthracite very little.

The principal usual waste of coal in its use for making steam begins in the furnace of the steam boiler through improper styles of furnace, or improper methods of firing. In order to treat this waste, we must first consider what coal is and how much heat-giving power it contains. This leads us a short distance into the discussion of its chemical constitution. If we submit a sample of coal to proximate chemical analysis by heating it in a crucible, we find it consists of four constituents: first, moisture superficially contained among its particles, which may be driven off by a heat of 212° Fahr.; second, volatile combustible matter, which may be distilled by heating to a red heat in a closed retort; third, fixed carbon, which may be burned away by heating for a long time to a bright red heat in the presence of air; fourth, ash, or the incombustible residue. Take two typical samples of American coal, good anthracite and Pittsburgh bituminous, and their composition when thus analyzed may be expressed about as follows:

	Anthracite.	Pittsburgh.
Moisture	1	1
Volatile matter	5	33
Fixed carbon	84	60
Ash	10	6

But we must analyze these coals by another method known as ultimate analysis, and find their chemical constituents as follows:

	Anthracite.	Pittsburgh.
Moisture	1	1
Ash	10	6
Carbon, fixed	84	60
Carbon combined with hydrogen	3	18
Hydrogen combined with carbon	1	6
Hydrogen combined with oxygen	0.1	1
Oxygen combined with hydrogen	0.8	8
Nitrogen	0.1	
	100	100

The moisture, ash, nitrogen, oxygen, and that portion of the hydrogen which is chemically combined with oxygen, are incombustible or of no value as heat-giving elements, leaving us the useful materials, the carbon, and the remainder of the hydrogen. From scientific experiments made by European authorities we learn what amount of heat these

NOTE.—This article has been prepared from our stenographer's report of a lecture delivered by Mr. Kent at the Franklin Institute, entitled "Some Preventable Wastes of Heat in the Generation and Use of Steam."

combustible elements are capable of giving, as follows :

1 pound of carbon burned to carbonic acid (CO_2) = 14,500 heat-units.

1 pound of carbon burned to carbonic oxide (CO) = 4400 heat-units.

1 pound of hydrogen burned to water (H_2O) = 62,000 heat-units.

A heat-unit being defined as the amount of heat equivalent to that required to heat 1 pound of water from 39° Fahr. to 40° Fahr.; that is, 1 pound of carbon thoroughly burned gives off an amount of heat which if entirely absorbed by water would heat 14,500 pounds 1 degree.

Knowing the heat-giving power of the elements, we can now calculate the amount of heat which our two samples of coal are capable of giving off as follows :

	Anthracite.		Bituminous.
C	.87 × 14,500 = 11,615	.78 × 14,500 =	11,310
H	.01 × 62,000 = 620	.06 × 62,500 =	3,750
	12,235		15,060

This gives us a measure of how much heat we might expect to obtain by burning the coals, if we could burn them thoroughly and abstract all the heat generated. But the quantity in heat-units may be translated into another kind of unit more generally understood. It is found, according to the experiments of Regnault, the French scientist, and others, that 1 pound of water at 212° evaporated into steam at the same temperature absorbs 966 heat-units, so that 1 pound of carbon with a heating power of 14,500 heat-units is capable of giving off heat sufficient to evaporate from 212° into steam at the same temperature $\frac{14500}{966} = 15$ pounds of water. This is usually expressed by saying 1 pound of carbon can theoretically evaporate 15 pounds of water from and at 212°. In a steam boiler we usually feed the water into the boiler at some other temperature than 212°, and we always evaporate the water at some higher temperature, but knowing the number of pounds evaporated per pound of coal under actual conditions of feed-water, temperature, and steam pressure, we can calculate by means of steam tables published in engineering reference-books what is the equivalent evaporation from and at 212°, and comparing this with the theoretical heating value of the combustible portion of the coal, we have what is known as the efficiency of the boiler, or the percentage of heat utilized by the boiler. The difference between this and 100 per cent. is the waste heat, some of which may be preventable and some not preventable. For instance, suppose we had a very pure anthracite, and the heating value of one pound of its combustible portion was equal to 14,500 heat-units, which is equivalent to 15 pounds of water evaporated from and at 212°, and we had a steam boiler which gave in actual trial a result equivalent to the evaporation from and at 212° of 12 pounds of water, then the efficiency of that boiler would be 12-15 = 80 per cent.

Such results have actually been obtained in steam boilers in tests with good anthracite coal. At the Centennial Exhibition in 1876 thirteen boilers were tested, which gave results as follows, when reduced to equivalent evaporation from and at 212° per pound of combustible :

No. 1.	12.094	No. 8.	10.930
" 2.	11.988	" 9.	10.834
" 3.	11.023	" 10.	10.618
" 4.	11.906	" 11.	10.312
" 5.	11.822	" 12.	10.041
" 6.	11.583	" 13.	10.021
" 7.	11.039		

It will be noticed that the first five boilers in the list gave a result very near 12 pounds. After the fifth boiler the results decrease rapidly down to the thirteenth, which gave a result of only 10.02 pounds, or 20 per cent. less than the highest boilers on the list. As all these boilers were put in the best possible condition for test, were tested with good coal and skilled firemen, and yet gave results differing by 20 per cent., it may well be realized that in ordinary practice, with average firemen and in many cases badly proportioned and badly set up boilers, as well as bad types of boilers, the difference between the best practice and the worst is very much greater than 20 per cent. Another record of actual boiler tests, showing what may be expected in average practice, is found in a book on boiler tests recently published by Mr. George H. Barrus, of Boston. Selecting from this book all the tests of which complete rec-

ords are given with different kinds of boilers, with different firemen, with different coal and in different parts of the country, we find the results of the tests as follows :

Water evaporated per lb. coal.	No. of tests. Anthracite.	No. of tests. Semi-Bitum.	No. of tests. Bituminous.
Over 12 lbs.	...	6	..
11.5 to 12 lbs.	2	6	..
11 to 11.15 lbs.	10	5	..
10.5 to 11 lbs.	20	3	..
10 to 10.5 lbs.	11	5	1
9 to 10 lbs.	14	6	2
8 to 9 lbs.	8	3	..
6 to 7 lbs.	1	..	..
	64	34	3

Out of 64 tests with anthracite coal, only two gave a result over 11.3 pounds, and as shown in the Centennial tests a result of 11.5 pounds was obtained with five different types of boilers, and it may be obtained with any properly designed and set boiler, fired with good coal and a good fireman. Twenty-three of the 64 boilers gave a result below 10 pounds, or 20 per cent. less than the highest economy attainable. In the semi-bituminous tests, only six boilers out of 34 gave a result of 12 pounds, which figure is not difficult to obtain with this coal in any good form of boiler properly proportioned, properly set, and properly fired. From these figures it may be appreciated what an enormous waste of coal is continually going on in the United States in steam boiler practice.

Let us now consider the causes of this waste. First, is the waste due to improper burning of the coal? In burning anthracite coal, we may have too deep a bed of coal for the amount of draught obtainable, or too little draught for the thickness of coal on the bed, and in this case we will have imperfect combustion of the coal, burning the carbon to CO instead of CO_2, and obtaining from it only 4400 heat-units per pound, instead of 14,500. This is an easily preventable waste, for this condition does not obtain to any extent if the relations of thickness of bed and of draught are such as to make the fire very hot and bright. If the fire is dull and sluggish, imperfect combustion may be suspected. A second cause of waste is exactly the opposite of the first, namely: too much draught for the thickness of bed, or too thin a bed for the amount of draught. In Professor Johnson's report of tests made for the United States Navy in 1844, he gives results of various tests of anthracite coal, and from them we learn that the Lehigh Coal & Navigation Company's coal is by far the worst of all the anthracites. Studying closely the record of this test, we find that the reason why this coal gave such a bad result was solely because too much air was allowed to pass through the fire, and the analysis of the chimney gases showed that twice as much air was passing through the fire as is customary in the best practice. If Professor Johnson had caused still more air to pass through the fire, no doubt he would have put out the fire altogether by chilling off the coal with cold air. But if, on the contrary, he had made his bed of coal on the grate twice as thick, he would have restricted the excess of air, and might have obtained the maximum result from that coal, instead of the minimum. These two matters—imperfect combustion through deficiency of air-supply and chilling the fire by excessive air-supply—are usually both within the control of the fireman. No specific directions can be given which will apply in each case, and each boiler owner should for himself determine the best conditions of thickness of bed, method of firing, etc., which will apply in his own particular case, and make his rules of firing from his own experience.

In burning bituminous coal we meet real difficulties. As shown in our proximate analysis, by heating the coal to a dull red heat, we drive off volatile combustible gases. In actual boiler practice the furnace in the boiler in this way becomes a gas-producer, and if the gases are driven off rapidly and at a low temperature, they are chilled by the comparatively cold surfaces of the boiler, and pass off into the chimney unburned. In the semi-bituminous coals the waste due to this unburned gas is not so very great, since the total amount of volatile matter in the coal is usually not as much as 20 per cent. of its weight, and such volatile matter as there is in it is distilled rather slowly, and it gets a chance to burn before leaving the furnace. In all coals mined west of the Allegha-

nies, however, constituting the truly bituminous coals, and which are far greater in quantity than the anthracite and the semi-bituminous put together, the volatile gases are much larger in quantity, and are distilled rapidly at a low temperature, and it has not yet been found possible in average practice to prevent the escape of a large portion of these gases with their accompaniment, smoke. The pall of smoke which rests over all our cities in the West is a monument to our bad engineering in not having found a way to practically utilize these gases, which are thus sent to waste. In ordinary boiler practice, with boilers as now set, all of this waste is not preventable, but that it is entirely preventable with different setting of boilers is clearly shown by the experience in steel melting furnaces, in which the gas is first distilled in a chamber known as a gas-producer, and is then carried through hot chambers of firebrick, and heated to a high temperature, and burned with a sufficient supply of air, which has also been pre-heated by passing through similar hot chambers. With this apparatus the gases are thoroughly burned, and no smoke whatever is made. The only thing which prevents this furnace being applied to a steam boiler is the cost of construction and of maintenance. It is, however, perfectly possible, with a much simpler apparatus, to save very much of the waste gas and prevent much of the smoke, and this apparatus consists simply of a large firebrick oven, built in front of the boiler, which serves both as a gas-producer and a combustion-chamber. The conditions necessary for burning bituminous coal properly are that the gas should be heated, and the air used to burn it should also be heated, and that the combustion should be carried on in intensely hot chambers, and that time enough must be given for the gases and air to thoroughly mix together before they are allowed to escape. These conditions can be provided in a properly built oven with air-heating flues in it, but they cannot be provided in the ordinary boiler-setting, because the latter does not give sufficient room. The next direction in which waste may be found in steam boilers is in the boiler itself. If it has an insufficient extent of heating surface, the gases, although properly burned in the furnace, may be allowed to pass into the chimney too hot. Another cause of waste is that with sufficient extent of heating-surface this surface may be so placed as not to be efficient ; that is, the gases may be allowed to be short-circuited, or take short passages from the furnace to the chimney, without passing uniformly over the whole extent of the heating-surface. I have found this trouble in ordinary tubular boilers, in which the hot gases, after passing under the boiler, had a tendency to return through the upper rows of tubes and neglect the lower rows. The latter were, in consequence, rendered ineffective, and the gases passed into the chimney at a higher temperature than if they had been compelled to sweep uniformly over the whole extent of heating-surface. Another cause of waste is the unclean condition of the boiler inside or outside or both. Scale on the water side of the heating-surface of a boiler and soot on the opposite side are both non-conductors of heat, and their presence leads to waste.

The indications of waste in steam-boilers are very plain. First, if the conditions of firing, draught, thickness of bed, etc., are right, there will be a very high temperature in the furnace. If there is a low temperature, either from imperfect combustion or from too great amount of air, there will be a waste, so that high temperature in the furnace is the first condition of economy in a steam boiler. The second prime condition is low temperature in the chimney. The heat produced in the furnace must be absorbed as completely as possible by plenty of heating-surface, and by clean heating-surface, and by surface properly disposed so as to intercept the currents of gas, and the result will be a low temperature in the chimney. Smoke is also an indication of waste, and wherever smoke is seen there also will be unburned combustible gases, which, as before stated, may be prevented. Other wastes in steam boilers may, however, exist, although there is a low temperature in the chimney, such as passage of cold air through the rear portion of the furnace, which the fireman is very

apt to leave uncovered. Second, leaks of air through the setting of the boiler. Third, leak of water into the flue-passages. Still another cause of waste quite frequently found is leaky blow-off-valve, where the valve discharges into a sewer and its leaky condition is not observed. Another cause of waste in a steam boiler, which is found in some establishments, is the waste of steam through the safety-valve. In some places where the demand for steam is irregular, but when needed it must be at a certain pressure and the boilers are not safe to be carried at much higher pressure, the safety-valves must be set at very little above the working pressure. When the work ceases for a short time, steam accumulates in the boiler and is blown off in the safety-valve. The remedy for this kind of loss is to have stronger boilers in which the pressure can be allowed to accumulate to a considerable point above the working pressure. In all places where the demand for steam is irregular, there should be great attention paid to the regulation of the damper, so as to prevent fuel being wasted when the demand for steam is small. Another cause of waste in a steam boiler is too small a grate-surface, causing the grates to be easily choked with clinker, and requiring more work of the firemen to keep them clean. Every time the fire is cleaned there is a waste caused by cold air rushing in the doors and by unburned fuel being withdrawn with the clinker.

Waste Heat in the Chimney.—With a properly set boiler, running to its normal capacity, it is not usually practicable to reduce the temperature of the flue to less than 100° in excess of the temperature of the steam in the boiler, or say to 400°. In actual practice 500° is more common than 400°, and in bad practice I have seen over 1000°. But if 400° is the lowest we can get, and the temperature of the air entering the boiler-room is 80°, the hot gases leave the boiler 320° higher than the temperature of the air entering. As the temperature of the fire is not usually much above 2000°, say 2400° as a maximum, the heat thus lost in the chimney is from 13 to 16 per cent. of the total heat generated by the coal. This loss is unavoidable with an ordinary boiler and chimney; first, because a moderately high temperature is necessary to make a good draught, and second, as already stated, we cannot reduce the temperature of the gases down to the temperature of the steam. But much of it may be saved by the use of an economizer or set of tubes placed in the chimney, through which the feed-water is passed, and heated from the entering temperature to nearly or quite that of the boiler. In large plants considerable economy of heat may be had by use of these economizers, using either a very high chimney or better forced draught, either blowing air in under the grate or exhausting it out after it passes the economizer.

We now consider briefly some of the wastes in the use of steam, supposing we have prevented all the wastes that we can in the steam boiler. The first waste in the use of steam is due to radiation of heat from the steam pipes. I copy the following from a published table, showing how much horse power may be lost from uncovered steam pipes.

2′ pipe, 1 H.P. lost for every 132 feet long uncovered, 75 pounds' pressure.
4′ pipe, 1 H.P. lost for every 75 feet long uncovered, 75 pounds' pressure.
6′ pipe, 1 H.P. lost for every 46 feet long uncovered, 75 pounds' pressure.
8′ pipe, 1 H.P. lost for every 40 feet long uncovered, 75 pounds' pressure.
12′ pipe, 1 H.P. lost for every 26 feet long uncovered, 75 pounds' pressure.

In the steam engine itself the wastes are numerous. First, that due to condensation of the steam as it enters the cylinder. This may cause a waste of anywhere from 10 to 50 per cent., or even more of the whole amount of steam used. Second, is the waste of steam in engines which are overloaded, due to exhausting the steam at too high a terminal pressure? Third, the waste of steam in high-pressure engines which are not loaded heavily enough by exhausting the steam below atmospheric pressure, and requiring the engine itself to do the work of pushing this low-pressure steam out against the pressure of the atmosphere. This cause of waste becomes a very serious one in the high-pressure non-condensing compound en-

gine. The last two named sources of waste can be prevented as much as is possible only by properly proportioning the engine to the work to be done. If the engine is to be run at a uniform load, the expansion of steam should be carried in it to such a point that the steam when exhausted will be at or near the back pressure in the cylinder. Cylinder condensation has never been entirely prevented, but, as we know its causes, we can modify them to a great extent. Too short cut-off involves expansion in high-pressure engines extending below the atmosphere, but also increased cylinder condensation. We therefore, in high-pressure engines, find that the maximum economy is obtained in single-cylinder engines when the cut-off is between ¼ and 1-5 of the stroke. Earlier cut-offs and later cut-offs both give worse economy. If we wish to economize steam still more than we can do in the single-cylinder engine, we must use a compound engine, and to get the maximum economy attainable with present practice we must expand the steam in three cylinders, beginning with steam of about 160 pounds' pressure or upward, and extending from 16 to 20 times. The range of wastes in the steam engine may be understood from the following table, showing what may be expected to be the water consumed per horse power per hour in different types of engine :

Common direct-acting pump, 100 pounds and upward.

Old-style slow-speed throttling engine, non-condensing, 45 pounds and upward.

Modern high-speed automatic cut-off, 30 pounds and upward.

Compound high-speed automatic cut-off, 22 pounds and upward.

Corliss single-cylinder high-pressure, 20 pounds and upward.

Corliss single-cylinder high-pressure, condensing, 18 pounds and upward.

Corliss single-cylinder high-pressure compound condensing, 14 pounds and upward.

Corliss single-cylinder high-pressure triple-expansion condensing, 12½ pounds and upward.

Thus showing that the best triple expansion engine will use only ⅛ of the amount of steam used by one of the worst types of engine, and less than half of the steam that is used by what is considered to be a first-class engine in ordinary stationary practice. All the consumption of steam in excess of 12½ pounds per hour per horse power may be considered to be a preventable waste, but as triple-expansion and compound engines are very expensive, the interest on their cost and the increased cost of maintenance may in certain conditions and in certain localities be more than the saving in fuel. Generally it will pay to put in a triple-expansion engine in all cases where the power required is over 500 horse power, and the time of maximum service is more than 10 hours a day. For smaller horse powers and for time of maximum load less than 10 hours a day it will generally not pay to use such an expensive engine. If we take the engine which uses only 12½ pounds of water per horse power per hour, and estimate that for every pound of water taken into the boiler there is added to it 1100 units of heat to convert it into steam of the desired pressure, this gives 13,750 heat-units required per indicated horse power per hour. As a horse power per hour equals 1,980,000 foot-pounds of work, and this divided by 772, the mechanical equivalent of heat, gives only 2569 heat-units per hour theoretically required to produce one horse power. We have, therefore, as the efficiency of this engine in relation to the heat in the steam used $= \frac{2569}{13750} = 18.68$ per cent. If we have a boiler which gives 75 per cent. efficiency, then the combined efficiency of the boiler and engine is $18.68 \times .75 = 14.01$ per cent. So that, in the best modern type of engine, we obtain only 1-7 of the heating value of the coal used ; the other 6-7 are absolute waste, but as far as our present knowledge extends, they are non-preventable. There does not seem to be any possibility of greatly reducing the waste in the steam engine so that its consumption will be less than 12½ pounds her hour. In all steam engines we must throw away either hot steam, as in high-pressure engines, or a vast volume of hot water, as in non-condensing engines, and in the latter case there is no known way of recovering the heat from the water that we throw away so as to use

it again in the engine. It may be left for the next century to discover some way of obtaining mechanical energy from coal without the intervention of the steam engine, but at present there seems to be no prospect of such an invention.

The preventable wastes, however, are those enormous wastes which are indicated by the difference between a consumption of 12½ pounds per hour per horse power and the 25, 35, or even 100 pounds which are used in the various types of engines, and the still more inexcusable wastes which are indicated by the difference in the figures showing the best practice and the worst in steam boilers.

THE PURIFICATION OF FEED-WATER.

By Henry Harrison Suplee, M.E.



THE formation of scale in steam boilers is one of the most troublesome features connected with the generation of steam, and the earnest discussion and numerous remedies proposed are in themselves evidence that the importance of the problem is appreciated.

There are two general methods of meeting this question: one, by attempting to remove the scale from the boiler after it has been formed; the other, by the prevention of the formation of the scale by putting only pure water into the boiler. Prevention is better than cure in this as in other cases, and there can be no question that the true method of keeping a boiler clean is not to let it become dirty.

Pure feed-water is such a rare article that it may almost be assumed that all feed-water is is in need of purification, and the method of purification is in most cases more a question of time and care than of any especial difficulty. The most frequent sources of boiler scale are carbonate of lime, which is in chemical solution, and earth and clay, in mechanical suspension in the form of mud. Less frequently sulphate of lime is met with, and its removal is a more difficult matter, but the carbonate of lime and the mud are the great enemies of clean boilers. In addition to these impurities, there is always more or less organic matter present, usually floating on the surface in the form of a scum, and all such floating matter should be removed as well.

The methods which have proved most efficacious for this operation of purification are those which have been derived from a careful observation of the operations of nature. Mud can always be allowed to settle, and the clear water drawn off quietly above the deposit at the bottom, while floating scum can readily be skimmed off from the surface without disturbing the clearer strata below. The separation of the impurities which are in chemical combination must be effected by precipitation, followed by the same operation of settling which occurs in the case of impurities held in mechanical suspension. This simply means that the water must be heated to a comparatively high temperature and at the same time kept free from agitation, and that the heavier impurities should be given time to settle while the floating scum should be skimmed off, and that all this should be done before the water enters the boiler.

It is a well-known fact that carbonate of lime is separated from solution almost completely if the temperature is raised to the boiling-point, because the carbonic acid gas is driven off by the heat, and the lime is precipitated in the form of a white powder, which will settle to

the bottom of the vessel in which the solution is heated. This can readily be demonstrated by warming a solution of carbonate of lime in a glass vessel, when it will be observed that the previously clear solution will speedily become milky. While a somewhat higher temperature than 212 degrees is required for the complete precipitation of all the lime, yet for nearly all practical purposes that temperature is high enough. These facts being kept in mind, it is not difficult to design an apparatus by which the feed-water for a battery of boilers may be purified to an extent quite sufficient for all practical purposes.

The purifier, which is at the same time a heater, should in the first place be made large enough. This is a point too often overlooked, and in many cases heaters otherwise well designed fail of successful operation merely because they are too small.

A heater, to do its work properly as a purifier, should really be a sort of stagnant pool in which the water lies quietly, with merely a slow stream creating a slight current from the inlet to the discharge to the boiler. The outlet should be at the highest point, and to obtain the best results the form of a horizontal shell meets the conditions more fully than any other. The water can enter near the bottom at one end, and the outlet be placed near the top at the other end, the outlet pipe being carried down several inches from the surface in order to be below the floating impurities on the surface. This arrangement permits a slow current to flow through the tank, and if the latter is of sufficient volume the action is so sluggish that it does not interfere with the constant settling of the mud and precipitated lime. This point is of vital importance, for it makes no matter how fully the impurities are precipitated if they are in a current of such velocity that they are carried on into the boiler, there to be deposited in all the quiet nooks and corners which await them. Even if the boiler has such an active circulation that no chance is given for settling while active firing is going on, it must be evident that as soon as the fires are banked the circulation ceases, and the mud and lime settle and are sure to be baked hard and fast to the metal before morning.

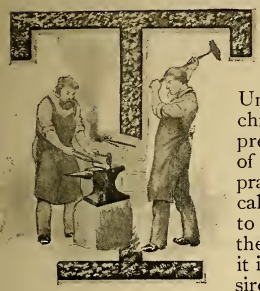
The method of heating the water in the purifier may be accomplished in more than one manner. In most cases a sufficiently high temperature may be obtained by the use of exhaust steam, and if sufficient tube area is provided no appreciable back-pressure need be produced. A good arrangement is one in which the exhaust steam enters a double head at one end, and then passes through a number of tubes, preferably of brass, to a similar head at the other end, and is there discharged. The feed-water should enter at the opposite end from the steam, so that the coolest water meets the hottest steam, and the joints of the tubes can readily be packed by rings of compressed rubber.

In a purifier of this kind there is a constant deposit of soft mud and precipitated lime, and this must be frequently removed, or it will soon be carried over into the boiler. Several large blow-off openings must be made in the bottom of the shell, and the heater should be blown off for not more than a minute or two not less than three times every day. At the same time the surface should be blown off also, proper connections being made for that purpose, and it is upon the care and frequency with which this is done that the completeness of the purification depends. It will be seen that there is nothing new or difficult about the simple apparatus here suggested, and it is based on two fundamental principles, namely : plenty of time for the impurities to settle, and frequent blowing-off to keep the vessel clear. When to these is added a temperature of not less than 210° F., there is no difficulty in obtaining feed-water pure enough for all practical purposes from nine-tenths of the sources available. When sulphate of lime is present, it may be necessary to use live steam to obtain a temperature sufficiently high to effect its precipitation, and in some cases this is worth all it costs, and for acid waters, such as are met in the mining regions, other methods must be adopted, but such cases are exceptional, and the present article is intended for general conditions.

THE INJECTOR.

By Professor R. C. Carpenter.

PART I.—EARLY FORMS.



THE injector was invented in 1858 by Henry Jacques Giffard, of Paris. Unlike most machines, it is not the product of any kind of evolution, either practical or theoretical. Giffard seems to have conceived the idea, stimulated, it is said, by the desire to produce a better device of feeding a boiler than a feed-pump recently brought out by a rival; it may have been suggested by the "jet-pump" which had been in use for a long time previous to this; but the idea that a jet of steam could be made to deliver its own weight and in addition a large amount of water against a pressure equal to or greater than the original steam was certainly original with Giffard, and, further, he was able to state a theory for its action that recent experiments prove to have been reasonable and correct. Even more than that, he produced a machine that has been altered but slightly during the thirty years of its existence. While the efficiency in many of the modern injectors is somewhat greater than in the first one, it is an open question if it is not due more to improvement in workmanship than in design.

Very little is to be found regarding the early history of the injector, but it seems to have been introduced into England in 1859 by Sharp, Stewart & Co., of Manchester, and into this country about the same time by Wm. Sellers & Co., of Philadelphia, Pa.

The jet-pump as it existed when Giffard's injector was invented was in the form of the water-jet pump as invented by Professor James Thomson in 1852. This is very similar to the blast-pipe which had been used for several years previously in the locomotive engine.

The jet-pump consists of a jet of steam or water applied at C, which produces a vacuum in the suction-pipe B, and discharges through the pipe D against considerable pressure. This differs essentially and radically from the steam injector and lacks nearly every feature which makes the injector a successful boiler-feeder.

The method of action of the injector, now well known, was explained by Giffard as follows: A jet of steam with a high velocity, which will be shown later to be practically about 1400 feet, rushes through the steam nozzle N (see Fig. 1) into the chamber K, driving out the air in the chamber K, which first rushes into the chamber P, and thence out through the pipe O. The vacuum in K induces first a rush of air from the suction-pipe S, and afterward a current of water which meets the jet of steam in the chamber K, and combines with it in the tube-connecting chambers K and P, this tube being termed the combining tube. Until water is drawn into the combining tube, everything is discharged through the open chamber P to the pipe O, termed the overflow. After water in sufficient quantity arrives, the steam is condensed, and it imparts its velocity to the water which leaps across the chamber P and delivers its products into the delivery tube D; farther than that the pressure in this tube is soon sufficiently great to lift the check-valve at C, to overcome the boiler pressure which holds that check-valve closed and to deliver a steady stream of water at low velocity into the boiler.

This explanation, which has in reality been verified by recent experiments, as will be shown later, was regarded especially by the educated engineers who had not seen the actual workings of the instrument as absurd and paradoxical.

The idea that a jet of steam could be made to return not only its own weight,

but a weight ten or fifteen times heavier than itself, against a pressure equal to the propelling pressure, seemed mechanically impossible and more absurd than the idea of perpetual motion. The mechanical work stored in a body by heating, although at this time known from the work of Joule, Rankine, and Clausias, does not at first seem to have been considered applicable to the action of the injector, although in later years it was shown to fully explain the action.

The belief in the paradoxical action of the injector it is said nearly prevented a patent being granted in the United States. A recent examiner in the Patent Office informed me that Giffard used every argument to convince the examiner to whom his application had been referred, that his invention related to a *useful* and *practical* machine, without avail; that he finally appealed to the commissioner of patents, who steadily supported the examiner in his views, but who was finally induced to observe the operation of the machine on a steamboat. This was sufficient to show that the invention was useful, and the patent was granted. The patent granted on the injector was given April 24, 1860, and is numbered 27,979. It is given to Henry Giffard, of Paris, for a device to feed boilers.

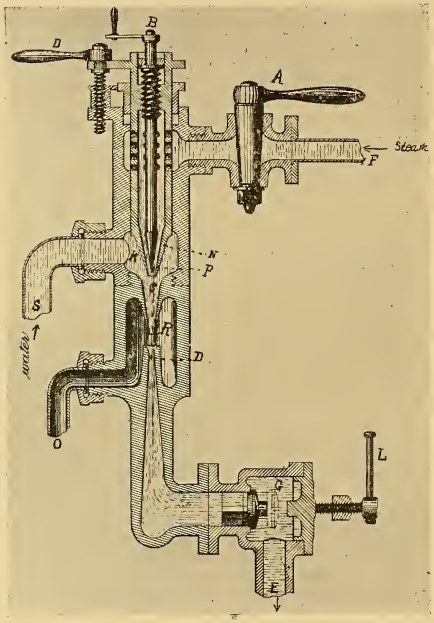


FIG. 1.—THE GIFFARD INJECTOR OF 1859.

The summary of claim is as follows:

"I claim, first, the method of supplying vessels under pressure with any non-elastic fluid by the direct action of steam or other gaseous fluid also under pressure, when this fluid is brought into direct contact with and enters the aforesaid vessels with the non-elastic fluid to which it has first given the necessary force to overcome the resistance substantially as described.

"2. I claim the general construction, arrangement, and combination of apparatus for forcing water or other liquids by the direct action of a jet or jets of steam, or other gaseous fluids, substantially as described."

The drawing which accompanies the patent is substantially the same as shown in Fig. 1.

The form of the Giffard injector, which is shown in Fig. 1, differs very little from the familiar ones of to-day, although its shape is more clumsy and the jets and nozzles for water and steam are not as smooth and well formed. Its especial adjustable features are to be noticed: first, the position of the steam nozzle, which can be moved to a greater or less distance into the chamber K by turning the hand-wrench, thus regulating the water-supply through the suction-pipe. Second, the size of the opening in the steam nozzle can be varied at will as the cone K on the end of the spindle B is moved in a greater or less distance. The size of the discharge-pipe can also be varied by the use of the screw L, which regulates the distance or play of the check-valve C. So in this injector we find every quantity of importance, viz: steam-supply, position of steam nozzle, water-supply, and water-discharge, subject to regulation to suit varying conditions, by movable parts within the instrument itself.

It is a matter of interest to note that these adjustable features are to be found in all the early injectors, but in the more recent ones these are fewer in number; while many injectors used with success have no adjustable parts in the interior of the instrument. The advantage of adjustable parts over fixed parts lies in this fact, that for varying conditions of steam-pressure or variation in temperature of feed-water a corresponding variation in amount of steam or quantity of feed-water may be required, in order that the injector will continue to work. Again, the position of the steam nozzle N through the combining

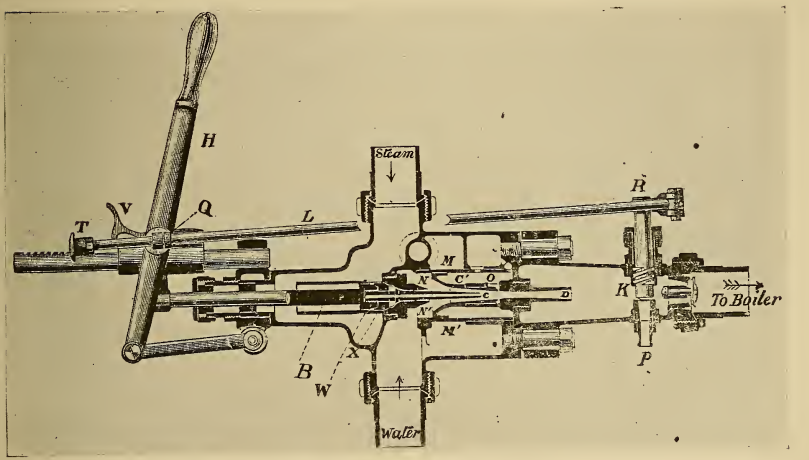


FIG. 2.—THE SELLERS INJECTOR OF 1876.

chamber has the effect to vary the size and consequently the work done in the suction-pipe. These adjustable features are, however, expensive, and if the conditions which affect the injector do not vary within wide limits, properly proportioned fixed nozzles can be used with success.

In every case, however, the essential parts shown in the Giffard injector are maintained with very little variation in form. These parts are: 1, the steam jet or steam nozzle; 2, the combining tube; 3, the overflow; 4, the delivery tube.

The Giffard injector, as we have seen, was an adjustable nozzle injector,

arranged so that both the water and steam-supply could be regulated within the instrument itself.

With this instrument, however, any marked change in the steam-supply required a corresponding change of the water-supply. This adjustment was made by turning either the handle *D* or *B*, and if not attended to, the instrument worked badly until readjusted to the new condition. If the proper relation between these parts were not maintained, there was either a waste of water and steam from the overflow

DIFFERENT FORMS OF INJECTORS.

In this country various types of injectors have been made, of which, as a rule, the later ones have been more simple in form than the earlier ones, while there has been little change in efficiency.

The various types of injectors may be classified as, first, *simple* and *double*, each of which may be subdivided into two classes, those with *fixed nozzles* and those with *adjustable nozzles*.

In the double injectors the water receives two separate impulses from the

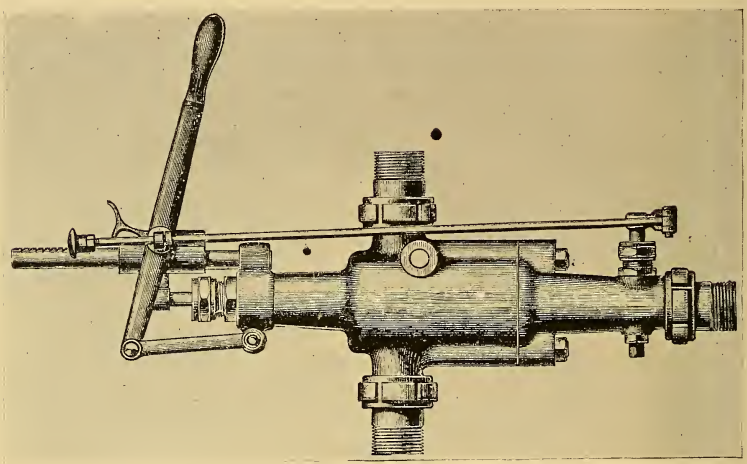


FIG. 3.—THE SELLERS INJECTOR OF 1876.

or an indraught of air. Injectors have been improved very little in this respect, for this action is characteristic of nearly all the injectors on the market to-day, although the limits of change which affect the injector are much increased.

Many of these injectors are, however, termed automatic, yet the only self-adjusting feature on them is a check-valve opening outward, placed on the overflow. This is found to have a very beneficial effect and to make the injector in a measure self-adjusting, as the shock due to the sudden opening and closing of this valve often has the effect to restart the injector.

steam; not that the same steam acts twice, but the water, after being acted on by one steam jet, is acted on later by a second jet. It is in effect the same action as though one injector delivered water into the suction of a second one, so that the second receives water already under pressure, a familiar illustration of which is seen in the Hancock inspirator, the Park injector, and in certain forms of the "Little Giant" and the "Sellers."

It is not the object in this article to describe the various forms of injectors that are on the market, but it does seem necessary to call attention to certain forms of injectors which will serve as types of the various classes already de-

scribed. In the brief description that follows, the order will be rather of historical development than of simplicity, although this order may bring the more complex productions first.

The Sellers injector of 1876 (see Figs. 3 and 4) follows very closely in the line of the Giffard injector in its general type, but has in addition an ingenious arrangement of levers for starting, so that when the steam is first turned on the overflow *P* shall be opened, but when the steam is turned further on by pulling out the lever *H*, the overflow-valve will be closed by the connecting-rod *L*. Again, this injector is thus making the injector a double one. The Sellers self-acting injector of 1887 in Fig. 4 is much more simple in form, as we have in this case fixed nozzles, and instead of the complex overflow-valve, as in the earlier form, we find a simple check-valve on the overflow. This check-valve can be closed when it is desired to pass steam through the injector to heat up the feed-water. A form intermediate between these and built by the same maker is still more simple, with no adjustable parts within the instrument itself.

The Hancock inspirator is a double injector formed so that the discharge

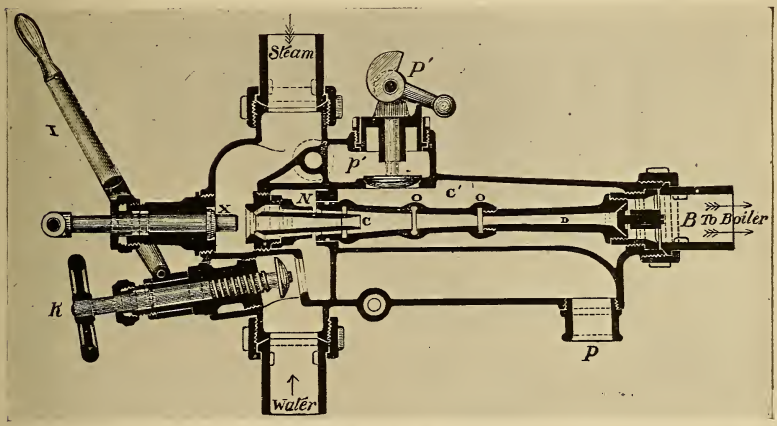


FIG. 4.—THE SELLERS INJECTOR OF 1887.

provided with a combining nozzle attached to a piston in such a manner that it will approach or recede from the steam nozzle *A*, as the pressure may predominate in the chamber *C* or in the chamber *N*. If the injector is not receiving sufficient water, the pressure in chamber *N* is in excess and the tube is moved farther away, thus opening up the water-supply; on the other hand, if there is too much water, the pressure in the chamber *C* will be in excess and the water-supply will be lessened by the motion of the combining tube toward the steam jet. After the water is well into the combining tube, it is acted on by a second jet of steam from the nozzle *C*, of the first injector is the supply to the second injector. Each injector is furnished with separate starting-valves; the first is termed the "lifter," the second the "forcer." The overflow is connected onto the second injector, but there is a by-pass-pipe with a valve, so that when this is opened and the second starting-valve closed the injector is essentially a simple injector. To start the injector, this by-pass-valve and overflow-valve must be opened after water appears at the overflow, open the starting-valve to the second injector, close the by-pass-valve and the overflow-valve. These directions are somewhat confusing to the novice, who does not

know the office performed by each part in the operation of starting.

A later form of this inspirator is furnished with connecting-levers so that the complete operation of starting is performed by simply moving the starting-lever. The Park injector is a double injector of very simple form in which both steam jets are in the same line. The operation of starting is very simple indeed.

Simple injectors. The simple injectors on the market are very numerous, and are used with satisfaction by a large class. These injectors differ from each other principally in details of manufacture; a few, and, so far as the writer knows, those of the early type, are made with movable nozzles; but most of these injectors are made with fixed tubes, and contain no adjustable features within themselves, excepting that a check-valve opening outward is almost universally placed on the overflow.

In the early forms of Schaeffer and Budenberg injectors the steam-supply was regulated by a cone, which was carried in or out by the motion of a handle on a spindle. This moved past a graduated arc, on which was marked the proper opening for each steam-pressure. The later ones are somewhat more simple, the Peerless being provided with the cone-valve, but is not furnished with a graduated arc, showing the proper opening of the valve. The Manhattan is not furnished with a cone-valve. The peculiarity of all these injectors is the flap-nozzle in the combining tube *C*. This is virtually a check-valve opening outward, and in case the pressure in the combining tube becomes greater than atmospheric, this flap-nozzle flies out and relieves the pressure almost instantly. The injector is provided in addition with a check-valve *F* in the overflow.

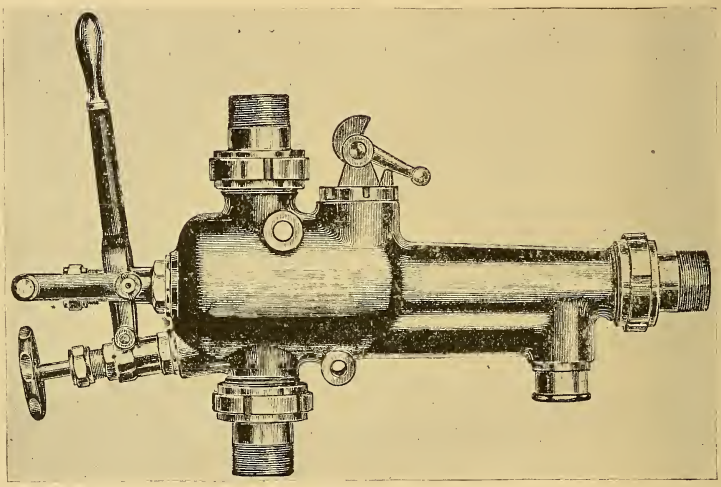


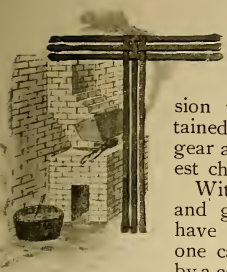
FIG. 5.—THE SELLERS INJECTOR OF 1887.

Illustrations of various other injectors will be printed with the second part of this article. No description seems necessary, as they differ simply in form and details. In the Pemberthy and Metropolitan injectors, the combining tube is made in two distinct parts, the first part being termed the suction-jet, although it is not clear why the complete separation should make any especial difference in the working. It is claimed, however, that the use of the suction-jet increases the limits of the injector.

(To be concluded in February issue.)

CUT-OFF AND COMPRESSION IN CORLISS ENGINES.*

By Professor James B. Stanwood, M.E.



THE narrow range of cut-off and the small amount of compression that have been obtained by the Corliss valve-gear are perhaps its weakest characteristics.

With it the latest cut-off and greatest compression have been so related that one can be extended only by a corresponding diminution of the other. Though the limits to these functions are narrow, yet they have been adjusted to embrace, for simple engines, the most economical conditions as to expansion, and admit of sufficient compression for smooth running at ordinary speeds.

The relation existing between these two vital points of this famous gear we will consider somewhat in detail, as it will be of value to a clearer understanding of the modification by which both can be increased.

With a single eccentric releasing gear, the eccentric controls four important points in the movement of the valves, viz: the lead, the point of maximum cut-off, the release, and the compression. Figs. 1, 2, 3, and 4 show the relative positions of crank and eccentric corresponding to these four vital points. The proportions here shown are what are usually found in practice; thus the angular advance of eccentric is 15°; lead angle, 6°; exhaust lead angle, 9°; these give piston positions (angularity of connecting-rod neglected) as follows: latest point of cut-off (by releasing gear) $\frac{37}{100} = A\ B$ (Fig. 2), release $\frac{96}{100}$ (Fig. 3), compression $\frac{96}{100} = A\ B$ (Fig. 4).

It is well known that the maximum cut-off controlled by the governor takes place when the eccentric is at the extreme position of its travel, and depends upon the angle through which it revolves from a position corresponding to that of the crank when at its dead center or to angle $X\ O\ Y$ (Fig. 1) equal to $A\ O\ Z$ (Fig. 2) equal to 90° angular advance of eccentric.

If more compression is required it can only be obtained, with same exhaust opening, by giving the eccentric more angular advance; this reduces angle $X\ O\ Y$ (Fig. 1) $= A\ O\ Z$ (Fig. 2), which in turn reduces the time during which cut-off can act.

Table I indicates the amount of compression and the corresponding limit for cut-off for varying angular advances of eccentric.

As the angularity of the connecting-rod increases the range of cut-off at one end of the cylinder and decreases it at the other, Table II is given to show this effect for different ratios between connecting-rod and crank; the minimum value in each case is given, as in practice the cut-off is adjusted to be the same on either end of the cylinder, and consequently cannot be greater than the lesser maximum amount.

These tables show conclusively the narrow limits imposed by this gear. With the advance toward compounding and with the constant effort to maintain higher piston speeds, greater range is needed. For instance, in double- and triple-expansion engines, large mean effective pressures and the advantage of low range of temperature in each cylinder, in combination with high number of expansions, requires later cut-offs; or, again, in simple engines with Corliss gear the most economical point of cut-off is so near the maximum that engines are often used with cylinders of larger size than immediate conditions demand, to insure enough power for future use; then the familiar evils of light loads "show up"; with a greater range of cut-off, the maximum power being increased, smaller cylinders can be used and a more economical adjustment of expansions to load at all times obtained.

The advantages of greater compression are well known, but may be briefly stated; by preventing pounding it assists

* In *Engineering*, London.

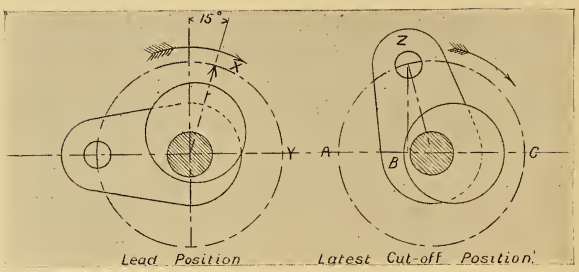


FIG. 1. FIG. 2.

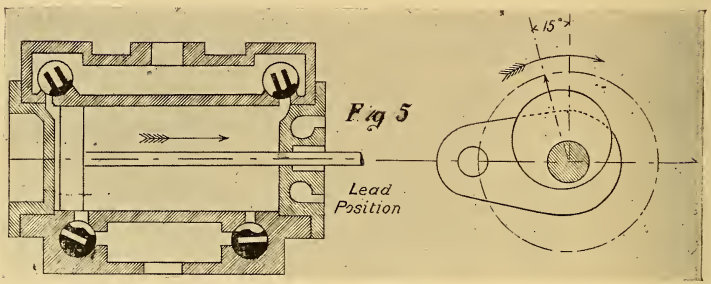


FIG. 5.—LEAD POSITION.

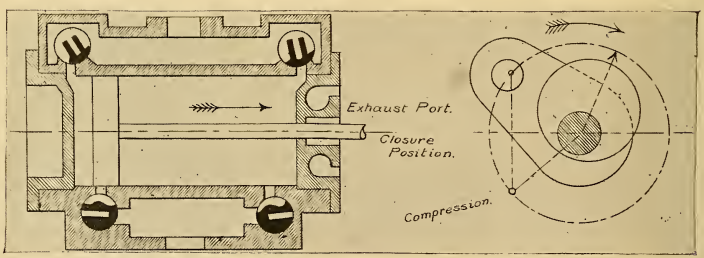


FIG. 8.—CLOSURE POSITION.

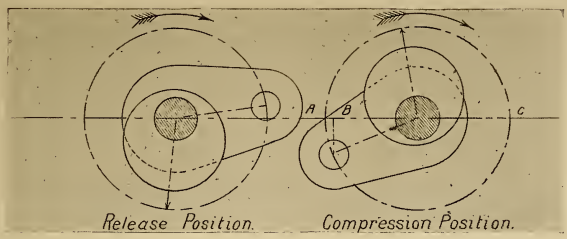


FIG. 3. FIG. 4.

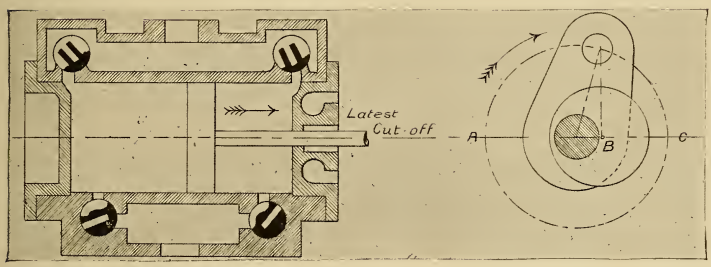


FIG. 6.—LATEST CUT-OFF.

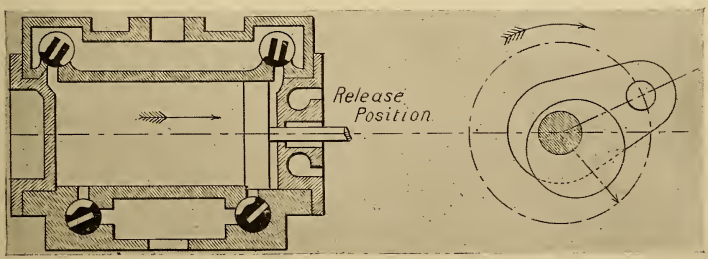


FIG. 7.—RELEASE POSITION.

in maintaining higher rotative speed, especially on condensing engines, simple and compound. This higher rotative speed in turn reduces cylinder condensation, and also permits of more power being obtained from a given cylinder. double wrist-plates, one system operating the steam-valves, the other the exhaust-valves; by this separation any cut-off can be obtained as well as any amount of compression, but at the cost of greater complexity of mechanism.

LATEST CUT-OFF AND COMPRESSION FOR VARYING ANGULAR ADVANCE.
Lead angle = 6°, exhaust lead angle = 9°.

TABLE I. Angularity of connecting-rod neglected.			TABLE II. Latest cut-offs for varying ratios of connecting-rod to crank.				
Angular advance.	Greatest compression.	Latest cut-off.	4 to 1.	4½ to 1.	5 to 1.	5½ to 1.	6 to 1.
deg.							
5	.999	.46	.33	.34	.36	.37	.38
8	.996	.43	.31	.32	.33	.34	.35
10	.991	.41	.29	.30	.31	.32	.33
12	.983	.40	.28	.29	.30	.31	.32
15	.967	.37	.25	.26	.27	.28	.29
18	.946	.35	.23	.25	.26	.27	.27
20	.929	.33	.22	.23	.24	.25	.26
22	.910	.31	.20	.21	.22	.23	.24
25	.877	.29	.18	.20	.21	.22	.22
28	.841	.27	.17	.18	.19	.20	.20
30	.815	.25	.16	.16	.17	.18	.18
32	.787	.23	.14	.15	.16	.16	.17

LATEST CUT-OFF AND MINIMUM COMPRESSION FOR VARYING NEGATIVE ANGULAR ADVANCE.
Lead angle = 6°, exhaust lead angle = 0°.

TABLE III. Angularity of connecting-rod neglected.			TABLE IV. Latest cut-offs for varying ratios of connecting-rod to crank.				
Negative angular advance.	Minimum compression.	Latest cut-off.	4 to 1.	4½ to 1.	5 to 1.	5½ to 1.	6 to 1.
deg.							
5	.992	.54	.41	.42	.44	.45	.46
8	.981	.57	.45	.46	.47	.48	.49
10	.970	.59	.47	.48	.49	.50	.51
12	.957	.60	.48	.49	.50	.51	.52
15	.933	.63	.51	.52	.53	.54	.55
18	.905	.65	.53	.55	.56	.57	.57
20	.883	.67	.56	.57	.58	.59	.60
22	.860	.69	.58	.59	.60	.61	.62
25	.821	.71	.60	.62	.63	.64	.64
28	.779	.73	.63	.64	.65	.66	.66
30	.750	.75	.66	.66	.67	.68	.68
32	.719	.77	.68	.69	.70	.70	.71

Compression also assists in filling clearance spaces with steam economically.

These features indicate the advantages to be derived from any system of extending the range of the Corliss valve-gear. In England manufacturers of these engines use double eccentrics and

The system to be described to accomplish the same result has no mechanism other than the usual Corliss gear, with its single eccentric, wrist-plate, tripping devices, and dash-pots; yet, by a modification of construction of the cylinder, its range of cut-off is increased to a

greater extent, with an accompanying increase in compression.

This is brought about by removing the immediate control of both the compression and release from the eccentric, and handing it over to the piston of the engine itself. When this is done, the eccentric freed from these duties has only the point of lead to determine, and can be adjusted on the shaft in a position that will give a large range of cut-off.

To explain more in detail, Fig. 5 shows a steam cylinder in which the exhaust-ports are placed within the limit of the piston's stroke; by allowing the piston to pass over these ports compression is obtained to any required amount; we shall directly see what latitude it gives to the valve motion. By proportioning the piston head of suitable thickness, it can be made to uncover the exhaust-port on its back edge in such a manner as to permit release to occur at the correct time. To successfully carry out these duties certain conditions are imposed upon the exhaust-valves; but fortunately they bear such relations to the eccentric's position on the shaft as to permit it to have negative angular advance—the requirement for all releasing gear cut-offs acting later than half-stroke. These conditions are twofold: first, the closure of the exhaust-valve should be complete before the piston, under the action of incoming steam, has uncovered the exhaust-port; second, the exhaust-valve at the opposite end of the cylinder should be wide enough open to permit easy egress of steam at the instant the piston on its inner edge closes the other port opened previously for preliminary release.

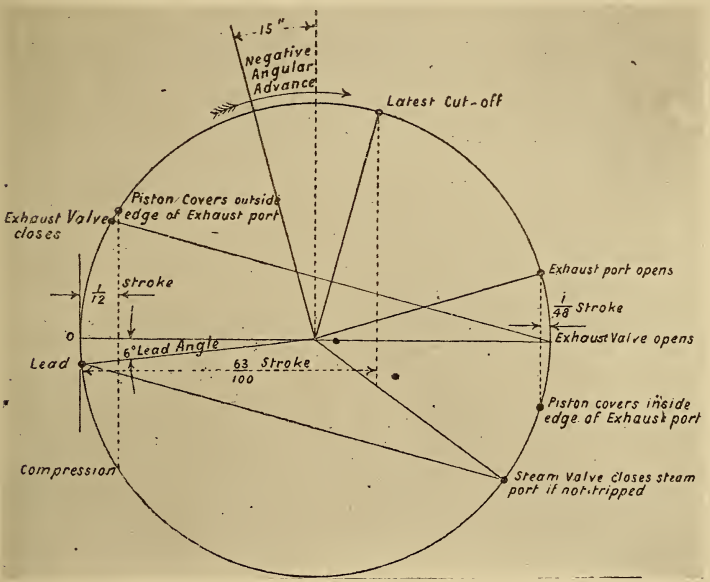


FIG. 9.

The eccentric has now, as in the usual gear, four points to control; but they occur at different intervals of time than before. They are, viz: the lead, the limit to cut-off, the opening of release at proper time on the return-stroke, and the closure of the exhaust-port before the piston uncovers it on its forward

stroke. Figs. 5, 6, 7, and 8 show these four positions for eccentric and crank; Figs. 5 and 6 showing clearly the range of cut-off secured by negative angular advance. Observe what is obtained by this arrangement—the cut-off can occur anywhere between *A* and *B*, Fig. 6; the exhaust-valve begins to open the instant the crank is at end of stroke; it has no lead, but steam has been released some few degrees before (Fig. 7) when the piston on its back edge uncovered the exhaust-port; when it closes the port on returning, the exhaust-valve is well open, as the eccentric during this period has its maximum motion. The compression begins at the instant the piston covers the port as it approaches the end of its travel, the exhaust-valve is not closed until just before the piston uncovers this port (Fig. 8) when starting out again on a new stroke. The maximum cut-off is $\frac{63}{100}$ stroke, the exhaust opens at $\frac{97}{100}$ stroke, and compression begins at $\frac{92}{100}$ stroke. By Professor Sweet's valve diagram (Fig. 9) the whole operation is shown at once. In this case the lead angle is 6°, angular advance (negative) 15°, exhaust lead angle (by eccentric) 0°

The fact that the exhaust-valves have to be closed before the piston, at the beginning of each stroke, shall uncover the exhaust-ports, determines a minimum distance that such a port shall be placed from the end of the cylinder, for any given negative angular advance of eccentric; this distance determines the amount of minimum compression. For the purpose of showing the relation that exists between this minimum amount of compression and varying amounts of negative angular advance, Table III has been calculated; it also gives the corresponding latest points of cut-off.

The angularity of the connecting-rod with this, as with all other valve-gears, causes an interference which reduces the maximum limit for cut-off. Table IV shows what the practically obtainable points are for varying ratios of connecting-rod to crank. Tables I and II should be compared with Tables III and IV to give an idea of gain in both cut-off range and amounts of compression of the new over the old system.

Angular advance.	Maximum compression.	Latest cut-off. Angularity of connecting-rod neglected.	Latest cut-off. Ratio of connecting-rod to crank.	
			5 to 1.	6 to 1.
Deg. 15	.967	.37	.27	.29
Negative angular advance.	Minimum compression.			
Deg. 15	.933	.63	.53	.55

It should be remembered that the values for latest cut-offs given in these tables are in reality the piston positions when the cut-off valves are tripped; the actual cut-off occurs slightly later, as there is an appreciable amount of time occupied in closing the port, during the fall of the dash-pots; the piston all the while traveling on under steam.

Above is given a comparison of two practical cases of the two systems of valve-gear, with positive and negative angular advance.

It may not be well-known, but it is nevertheless a fact, that sulphur is an excellent lubricant, and bearings which have a faculty of getting hot can be greatly improved by the use of a small quantity. For marine engines especially the sulphur is at times invaluable, for, while a stationary engine can be stopped a short time without great inconvenience, a hot journal or bearing is one of the last things for which a large steamship should be compelled to stop.

PIG IRON.—HISTORY AND A PREDICTION.

By William Kent, M.E.

THE following table shows in a condensed form the ups and downs of the iron trade in the United States for the past 30 years :

Year.	Production in tons of 2000 lbs.	Term, years.	Average increase per year, tons.	Average decrease per year, tons.
1860	731,544	.....	.....	.....
1873	2,868,278	12	178,061	.....
1876	2,093,236	3	.....	258,347
1882	5,178,122	6	514,148	.....
1885	4,529,869	3	.....	216,084
1890	10,307,028	5	1,155,342	.....
1891 est'd	9,000,000	1	.....	1,300,000 est'd

Skipping over the periods of depression, 1873 to 1876, and 1882 to 1885, and taking the years of maximum production in each period, we have the following figures, showing the rate of growth from 1860 to 1890 :

Year.	Production, net tons.	Term, years.	Average increase per year, tons.
1861	731,544	.....	.....
1873	2,868,228	12	178,061
1882	5,178,122	9	255,538
1890	10,307,028	8	641,113

Since the same causes which produced this wonderful growth during the past thirty years still exist and are likely to continue for many years to come, viz, the increase of population, the increase of wealth per capita, the increasing substitution of iron for wood, stone, and brick in construction, the increase of weight of rails and of all iron structures, we may safely assume that the average rate of increase during the next ten years will be not less than 1,000,000 tons per year, and predict that the production of iron in the United States by the year 1900 will have reached 20,000,000 net tons. The only causes which may prevent this consummation, as far as our present light extends, are war, pestilence, a succession of short crops, or some financial or political convulsion which may change existing economic conditions, such as the repeal of our present tariff laws.

Another set of figures from which the probable production in 1900 may be estimated is the production reached in the year at the end of each of the ten-year periods ; that is, 1860, 1870, 1880, and 1890. The figures are as follows :

Year.	Production, net tons.	Increase in 10 years, per cent.
1860	919,770	.....
1870	1,865,000	102.8
1880	4,295,414	130.3
1890	10,307,028	140.0

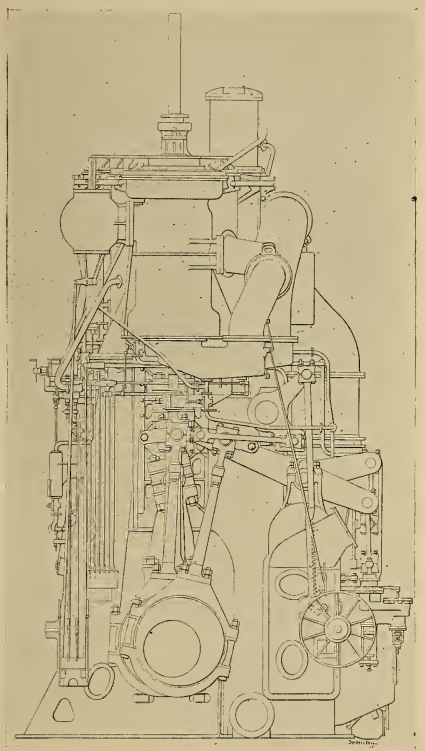
A production of 20,000,000 tons in 1900 would be an increase of only 94 per cent. over that of 1890. Each of the three ten-year periods before 1890 showed an increase of over 100 per cent., and the latest one 140 per cent., and there seems to be no reason for believing that the increase in the next ten years should be less than 100 per cent.



A GROUP OF ENGINE BUILDERS. THE RUSSELL BROTHERS, COMPOSING THE FIRM OF RUSSELL & COMPANY, MASSILLON, O.

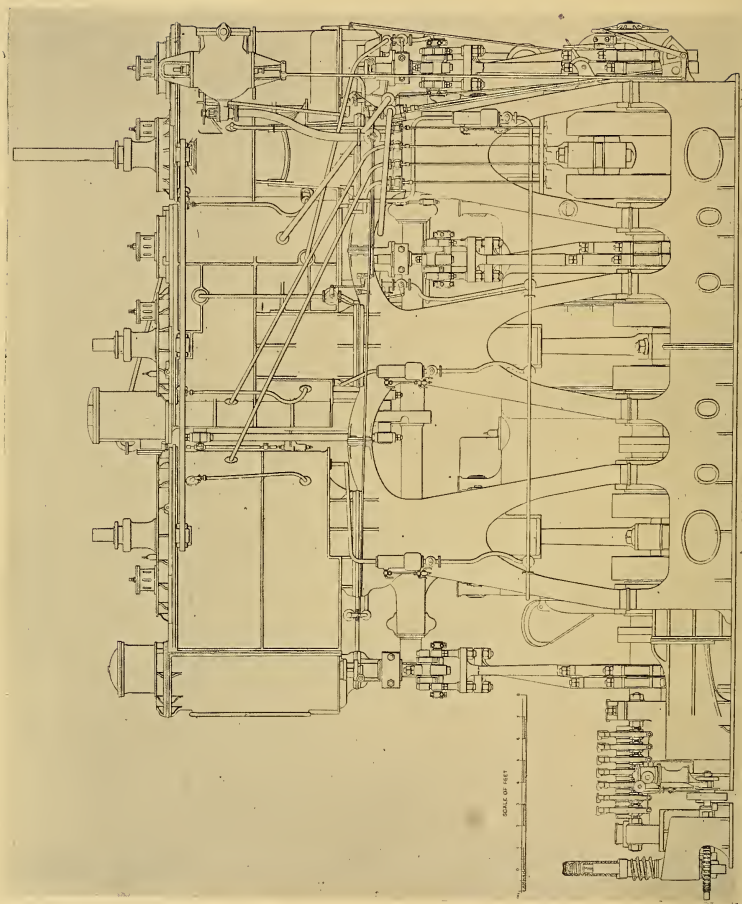
NEW MARINE ENGINES.

THE engravings of the triple-expansion marine engines, shown on this page and the page opposite, were made from drawings printed in *Industries*, of London. That



END ELEVATION.

journal gives the following description of the engines which were fitted in the Orient Steam Navigation Company's vessel *Ophir*, which was recently built by Messrs. R. Napier & Sons, of Glasgow. The *Ophir* is a twin-screw steamer 482 ft. long over all, 465 ft. between perpendiculars, 53½ ft. wide, and with a molded depth to the upper deck of 37 ft. The engines, of which there are, of course, two sets, are of the inverted direct-acting condensing type, and are fitted in separate compartments. They are of the type usually constructed by the above-named firm, and have cylinders of the following diameters: High-pressure, 34 in.; intermediate, 51½ in.; and low-pressure, 85 in., with a stroke of 54 in., the boiler-pressure being 160 lbs. per square inch. The cylinders are all steam jacketed, and the valve-

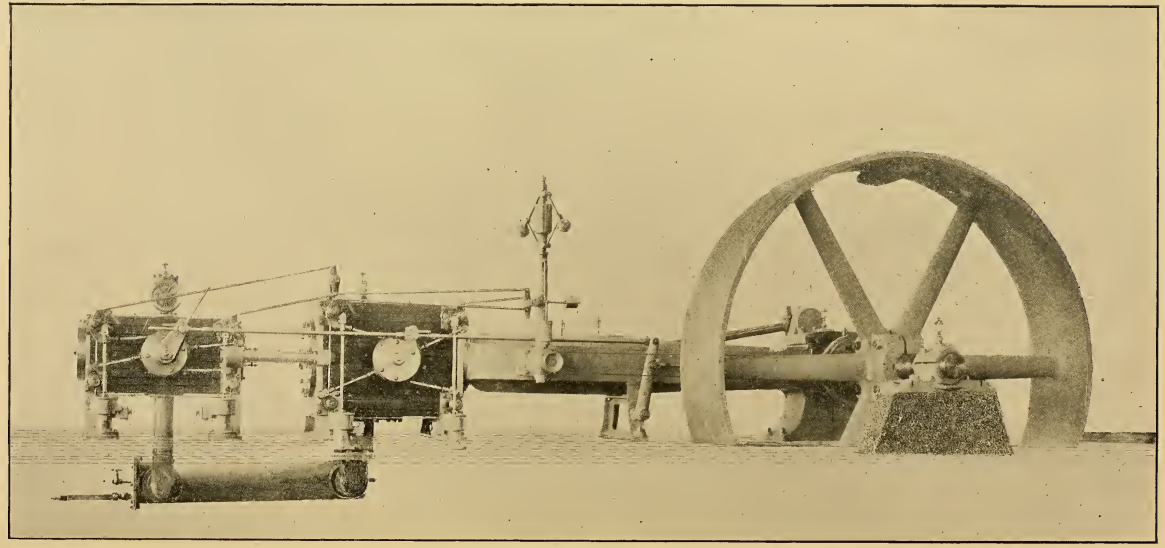


FRONT ELEVATION OF TRIPLE-EXPANSION ENGINES OF THE TWIN-SCREW STEAMSHIP OPHIR, BY ROBERT NAPIER & SONS, ENGINEERS AND SHIPBUILDERS, GLASGOW, SCOTLAND.

gear is of the ordinary link-motion type. The high and intermediate pressure cylinders have piston-valves, and the low-pressure cylinder has a double-ported slide-valve. Steam for these engines is derived from seven main boilers, placed in two compartments. Of these, five are double-ended boilers, each 15½ ft. diameter and 18½ ft. long, and two single-ended boilers, each 15½ ft. diameter and 10 ft. long. The former have each six furnaces, with Purves's ribbed flues, and the latter have each three furnaces. The stokeholds have been constructed for forced draught, with a provision for enabling the boilers to be worked with natural draught when in hot climates, all furnaces having separate combustion chambers. The stokeholds are fitted with powerful fans to secure perfect ventilation and circulation of air, especially in the Red Sea. These fans can also be adapted to produce forced draught should an unforeseen emergency demand it. The propellers have each three manganese-bronze blades, the extreme diameters being 17 ft. and pitch 23 ft. 3 in. The propeller shafts are placed at a distance of 11 ft. 7¼ in. each side of the center line of the ship, and project aft of the skin of the ship 39 ft. In case the vessel should be requisitioned at any time for armed cruising purposes, the *Ophir* has been provided with extra large coal bunkers. The ordinary bunkers are arranged alongside and between the boiler-rooms, and in the wake of the water-line alongside of the engines. These will carry sufficient fuel to enable the vessel to steam 15½ days at an average speed of 16 knots, without refilling. This distance could be further augmented, if the holds were also used as coal bunkers, to a cruise of 130 days at an average of 10 knots. The *Ophir* was tested for speed on the measured mile on the Clyde in October last, and a speed of 18¾ knots was attained with the engines making 102 revolutions per minute and developing 11,400 H.P. In a 500 miles trip a mean speed of 15.8 knots was attained, with a coal consumption of 93.456 tons per day of twenty-four hours. The registered tonnage of the vessel is 6900 tons, the displacement being 10,600 tons. A fore and aft water-tight bulkhead separates the port from the starboard engine, and the boilers are similarly separated by transverse bulkheads. The complete separation of one engine from the other in this way rendered necessary the duplication of the machinery, including the auxiliary engines, thus providing unusual security against break-down. The duplication of parts, and the provision of alternative arrangements in order to meet every possible contingency, are points insisted upon by the Orient Company, and it is claimed that in the *Ophir* this principle has been carried much further than has ever been attempted. Weir's feed-water heaters and feed-engines supply the boilers. Worthington donkey engines, interchangeable with each other, made by Messrs. Napier, and Messrs. Brown Brothers' steam and hydraulic starting and reversing gear, have been provided.

The ventilation of the *Ophir* has been effectively carried out by Messrs. J. D. F. Andrews & Co., of 41 and 42 Parliament street, London, S. W. The apparatus comprises an air-compressor, having double-acting air cylinders, each 36 in. diameter and 24 in. stroke, driven direct by compound engines, having cylinders 13½ in. and 25 in. diameter respectively, with a stroke of 24 in. These compressors are capable of delivering 340,000 cubic feet of air per hour at a pressure of 6 lbs. per square inch. This quantity of air supplied to the inducing nozzles would, we are informed, be capable of inducing a current of air equal to 13,570,000 cubic feet per hour, a quantity greatly in excess of the possible requirements of this vessel. The compressors and engines are mounted on a strong cast-iron box which forms the air-receiver.

On page 224 is printed an engraving of a group of the members of the well-known firm of engine builders, Russell & Company, of Massillon, O. This engraving is a very interesting one from the fact that all the portraits shown are of brothers, who, as will be seen, are not now young men, but with one exception are all still engaged in the active conduct of their large and successful business.



BACK VIEW OF TANDEM COMPOUND CORLISS ENGINE CONSTRUCTED BY THE PHILADELPHIA ENGINEERING WORKS FOR LYMAN, FIELD & CO., NORFOLK, VA.

NEW TANDEM COMPOUND CORLISS ENGINE.

THE engravings on the pages opposite and following illustrate a small tandem Corliss engine built for and now operating at the milling works of Lyman, Field & Co., Norfolk, Va. The high-pressure cylinder is 12″, the low-pressure 22″, and stroke 36″, giving a ratio of 3.36 to 1.

It is intended to use steam at 125 pounds gage pressure and run at 90 revolutions per minute, giving a piston speed of 540 feet. At present the work does not require so much power, and a 100 lbs. steam is used. The principal dimensions of this engine are as follows :

Diameter of the throttle-valve	4″.
Area of each steam-port.	9 and 26 sq″.
Area of each exhaust-port.	13½ and 38 sq″.
Diameter of the piston-rod	2 1/8″.
Diameter of the crank-pin	4½″.
Diameter of the main shaft journal	9″.
Length of the main shaft journal	16.
Length of the main shaft	8 feet.
Diameter of the fly-wheel	12 feet.
Face of the fly-wheel	26 inches.

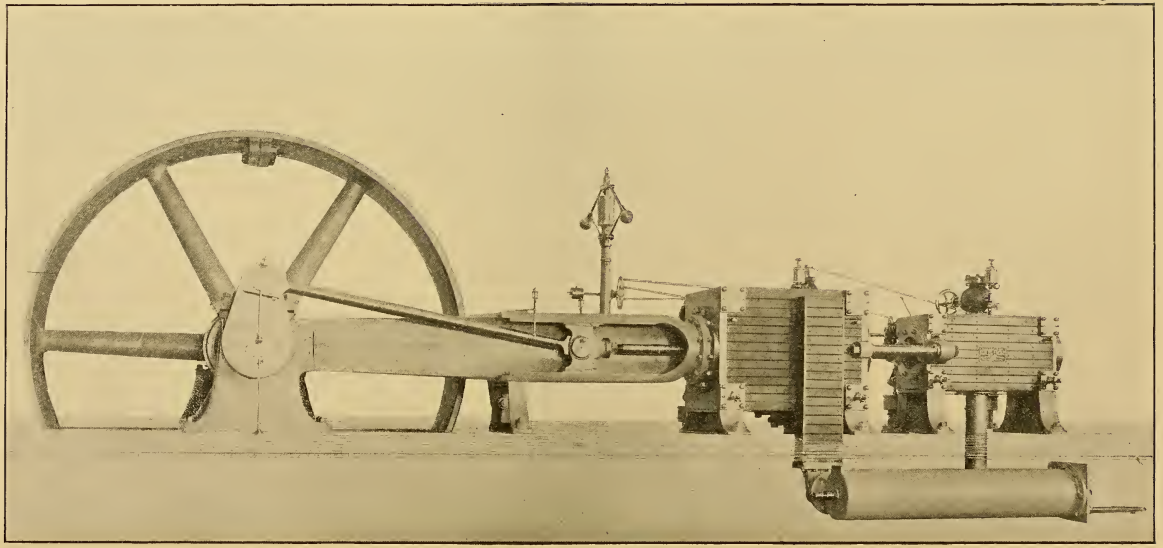
The receiver and its connections, including the space from exhaust-valves in the small cylinder to the steam-valves in the large cylinder, is four and one-half times the capacity of the small cylinder. The low-pressure cylinder can, therefore, have a reasonably short cut-off without excessive compression upon the small cylinder. The receiver is used as a reheater, live steam being introduced through the square flange-end shown and into twelve 1-inch pipes extending the whole length. These pipes are drained with a steam-trap. This receiver and all its connections are carefully lagged and packed with mineral wool (the lagging having been removed to show the receiver better in the photograph.)

It will be observed that the valve areas are very large, and consequently with careful adjustment the loss of pressure between the two cylinders is insignificant. The valve-gear releasing mechanism operates around a common center of the stems, as is usual in the most approved pattern of Corliss engines. The dash-pot is connected close up to the stem, so that its motion is very limited, and a very quick closing is effected. The dash-pot rod connects to the plunger, so as to avoid any tilting action, and thereby reduces the wear. In larger sizes we cover the tops of these dash-pots, but in the smaller ones there is not sufficient room. This plan, though possibly not so neat as some of the covered dash-pots, is preferred, as it does not tend to cant the plunger, and less friction is incurred in so important an action as the dash-pot when the instantaneous closing of the valve is desired. The makers who have estimated the time required in closing these valves say it is less than one one-hundred-fiftieths of a second, and therefore obtain a square sharp angle at closing, following the horizontal line during the steam admission. This horizontal line is obtained by the careful adherence to the principles of the lazy action used on all Corliss engines.

In none of the engines built by the firm does the piston travel more than one-seventh of the stroke before a full port is opened, and in some cases, particularly larger engines, this wide port is effected at one-ninth of the stroke. In this engine it is a fraction less than one-seventh.

This engine is supplied with an independent surface-condenser made by the Wheeler Condenser and Engineering Company, of New York, the condensing water being taken from the ocean.

The girder is of the ordinary Corliss type, with the following modifications : The girder is bolted to the pillow-block, but with through bolts instead of tap-bolts ; that is, the joining of the two is effected some distance from the pillow-block, permitting through turn-bolts to be used. The back web of the girder is made from two to three times as deep as the usual practice. The slides are bored instead of being planed, but not to a diameter equal to the distance between them, as is sometimes the practice, but to a small radius by special machinery, in this case the radius being 3¼″. This permits of the perpendicular member, or what may be called the front plate of the girder, being as close to the line of strain as the length of the cross-



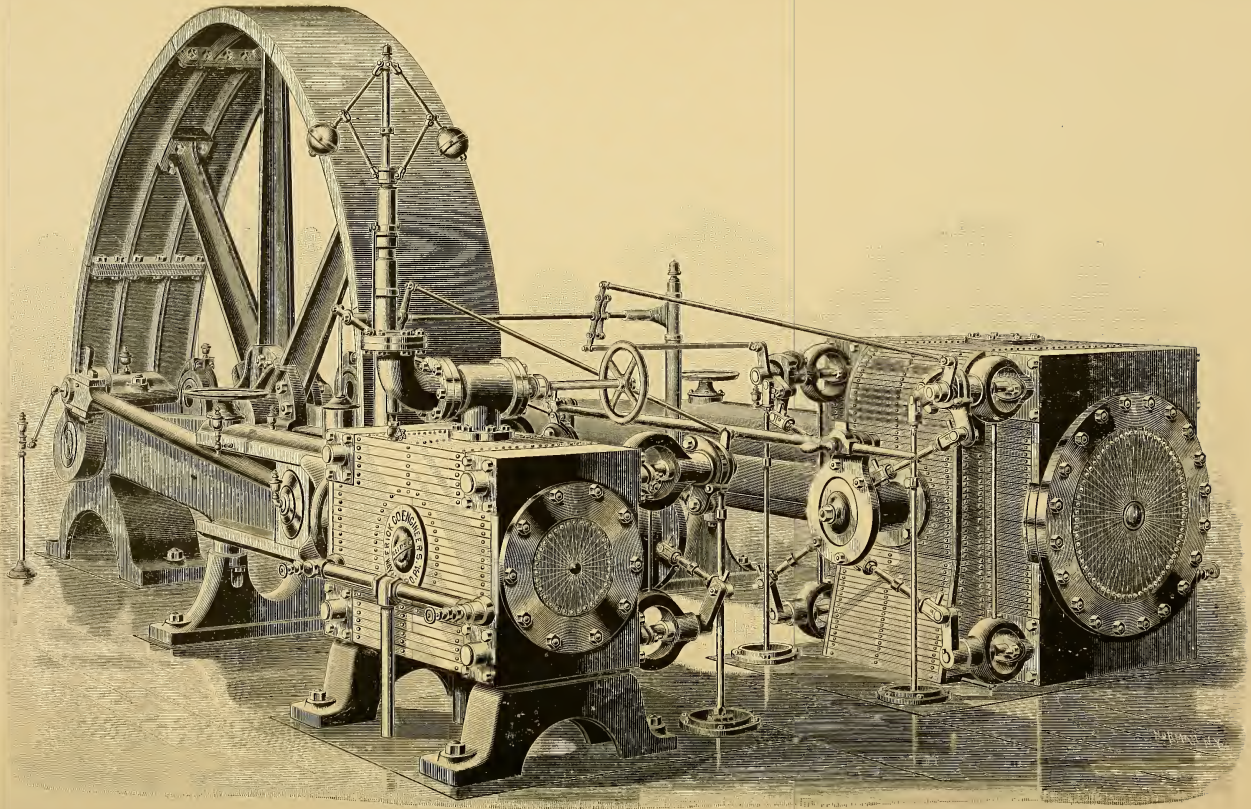
FRONT VIEW OF TANDEM COMPOUND CORLISS ENGINE, CONSTRUCTED BY THE PHILADELPHIA ENGINEERING WORKS FOR LYMAN, FIELD & CO., NORFOLK, VA.

head pin will permit ; thus securing the same advantage as is obtained in planed slides, but obtaining greater side-bearing and absolute accuracy, for in the machine in which these girders are prepared we bore the slides and face each end and drill all the holes without changing the piece except in one plane, as it is only desirable to bring the pads upon which the girder is first bolted to the several stops necessary in proceeding with the work on the slides, either end or back as the case might be.

Engines of this type, and as small as this, have not been introduced to any great extent. It is believed, however, that the remarkable economy to be obtained from them, and their comparatively low cost, will bring them rapidly into favor. It may be thought that they are necessarily much more difficult to take care of, and expensive men and repairs will more than neutralize the advantge in the saving of the fuel. This is an error. The engineers are rapidly being educated to the point of taking care of good machines, as it is well known that the Corliss gear works with so little friction that the wear is but slight and the attention required insignificant. The ordinary Corliss engine will consume 24 pounds of steam per H.P. per hour ; the ordinary slide-valve from 30 to 100, while this engine, the makers state, will do its work within its economical range on 16 pounds of steam per I.H.P. per hour. Taking fuel at an average cost of $3.50 per ton, it is apparent that the saving will give a good return for the additional investment.

R. C. CARPENTER.

R. C. CARPENTER, of whom a portrait is shown in the front part of this magazine, was born in Oakland county, Mich, in 1852, and prepared for college in the village schools in the immediate vicinity. He graduated from the Michigan Agricultural College in 1873, and from the Michigan University in 1875. After graduating he was employed for nearly a year as assistant engineer on construction on the Detroit & Bay City Railroad, after which he accepted the professorship of engineering in the Michigan Agricultural and Mechanical College, at Lansing, Mich., in which position he remained until 1890. Mr. Carpenter while in this position was also actually engaged as engineer of various enterprises in the vicinity. He planned and constructed several water-works systems and a number of heating plants, all of which are in perfect condition. He was also consulting engineer for one of the prominent manufacturing firms in the vicinity, and had quite an extensive practice as testing engineer. In connection with the college work at Lansing, Mr. Carpenter organized and put in operation the course in the wood- and iron-working shops in that institution, and also erected the water-works and steam heating systems. While employed at Lansing, two vacations were devoted to the study of astronomy in the Astronomical Laboratory at Ann Arbor, Mich., and two in special research in Cornell University. In 1888 Mr. Carpenter received the degree of M.M.E. from Cornell University. In 1890 he was appointed Associate Professor of Experimental Engineering in Cornell University in charge of the laboratories of Sibley College. Mr. Carpenter, who is writing a series of articles for this magazine, has been a correspondent at various times of some of the leading engineering and trade journals, among which may be mentioned *The Engineering News*, *Power and Steam*, *The American Engineer*, *The Metal Worker*, *The Clay Worker*, and *The Drainage Journal*. He is a member of the American Society of Mechanical Engineers, and has presented some of the most valuable papers on various topics which have been read before the society. He has written one book on the methods of testing, entitled "A Manual of Experimental Engineering," a second edition of which is soon to be published by John Wiley & Sons. Mr. Carpenter's work at the college is attracting much attention, and a number of articles on the investigation he is making will be published in this magazine.



CROSS-COMPOUND CORLISS ENGINE. BUILT BY THE FRICK COMPANY, ENGINEERS, WAYNESBORO, PA.

See page 241.

THE LOVES OF INVENTORS.*



THERE is no doubt that inventors do not, as a rule, make good lovers. The man whose brain is full of some great mechanical project, whose heart and soul are centered on the achievement of some wonder of wheels or pulleys, or fire or steam, has not much room for the softer feelings which supply so much of the poetry of common humanity. His love is given to his invention. Of it he dreams by day as well as by night; for it he makes his sacrifices, undergoes privations, and waits and labors with such patient endurance. He will often woo and marry, after the manner of men, but he will never become the "moonstruck," love-lorn individual which more purposeless men are capable of becoming. He will be a business-like, rather than an ardent, lover; and will make a dutiful, rather than an affectionate, husband; the romance of his life is his life's work, his invention, and as that goes well or ill so will his heart be light or heavy.

Some inventors have been far from happy in their lives. Arkwright had but a sorry time of it with that spirited "Lancashire lass," his second wife, who smashed the model of his spinning-frame one day in a fit of temper, because she deemed it (and perhaps not altogether unjustly) responsible for their poverty. What she thought of it all when, after separating from him, he accumulated a large fortune and allowed her £30 a year out of it, the annals of cotton-spinning do not inform us. We are told, however, that she never spoke ill of him, and would not permit anyone else to do so in her hearing.

Bernard Palissy complained bitterly of the impatience of his wife under the long trials of his experiments in enamels. "Even those from whom solace was due," he said, "ran crying through the town that I was burning my floor, so that I was regarded as a madman." Sir Humphry Davy, the inventor of the Davy lamp, found love something of a delusion, if not a snare. Writing to his mother, he said, "I am the happiest of men in the hope of a union with a woman equally distinguished for virtues, talents, and accomplishments." And in a letter to his brother he expresses his rapture thus: "Mrs. Apprece has consented to marry me, and when the event takes place, I shall not envy kings, princes, or potentates." The widow must have been a person possessed of great powers of fascination, for Sir Henry Holland makes mention of her as a lady who made such a sensation in Edinburgh society that even a regius professor did not think it beneath his scholarship to go down on his knees in the street to fasten her shoe. The sequel need not be dwelt upon further than to add that the marriage turned out to be altogether a mistake. Lilly, the astrologer and alchemist, could not see for himself sufficiently far into that future which he professed to be able to scan so clearly for others, to guard him against making a fool of himself by marrying. He caught a vixen, "of the temper of Mars," to use his own words, and the fact that she brought him £500 as dowry did not count for much in the way of compensation, seeing that "she and her relations cost him £1000."

But this was a trifling error of perception compared with that committed by Sir Samuel Morland, who, besides being secretary to Lord Thurlow and master of mechanics to Charles II, invented a speaking trumpet and other ingenious articles. Writing when smarting under the pain of heartless deception, he says, "About three weeks or a month since, being in very great perplexities, and

*From "Romance of Invention."

almost distracted for want of money, my private creditors tormenting me from morning till night, and some of them threatening me with a prison, there came a certain person to me, whom I had relieved in a starving condition, and for whom I had done a thousand kindnesses, who pretended in gratitude to help me to a wife, who was a very virtuous, pious, and sweet-dispositioned lady, and an heiress who had £500 per annum in land of inheritance and £4000 in ready money, with the interest since nine years, besides a mortgage upon £300 per annum more, with plate, jewels, etc. The devil himself could not contrive more probable circumstances than were laid before me; and when I had often a mind to inquire into the truth, I had no power, believing, for certain reasons, that there were some charms or witchcraft used upon me, and withal, believing for certain it utterly impossible that a person so obliged should be guilty of so black a deed as to betray one in so barbarous a manner. Besides that I really believed it a blessing from heaven for my charity to that person, and I was, about a fortnight since, led as a fool to the stocks, and married a coachman's daughter not worth a shilling; and thus I am both absolutely ruined in my fortune and reputation, and must become a derision to all the world." Sir Samuel, however, was too clever a man to allow himself to be kept down by such unholy fetters as these; besides, he lived in an age when the obligations of matrimony were at best but lightly regarded; so he survived the humiliation that his marriage brought upon him, and managed to forget the coachman's daughter in the courtly atmosphere in which he long moved.

It is pleasant to turn from a picture like the foregoing to one of the few stories in which it is clearly shown that the passion of love has had a real influence in advancing the interests of the inventor.

On the tomb of Quentin Matsys, erected a hundred years after his death in the cathedral of Antwerp, are inscribed in letters of gold the words, "*Connubialis amor de mulcibre fecit Apellam*" ("Connubial love made him an Apelles"). It was, indeed, his pure love for a beautiful woman that was the inspiration of all his greatness. The "blacksmith of Antwerp," as he came to be styled, was born in poor circumstances in the year 1466, and for a long time supported himself and his mother by working as a locksmith. It was while laboring in this humble capacity that he fell in love with the daughter of a painter of Antwerp. The difference in their stations seemed at first an insurmountable obstacle to the success of his suit, but the ardor of his passion made him eloquent, and the comeliness of his person made him attractive, and he in the end won the heart of the young lady, and they might have been united had his rank in life been equal to hers. As it was, the painter declared that no one but an artist should have the hand of his daughter, and had already in his mind set apart a certain youth of birth and parts, one of his own pupils, for the honor. Even the damsel, prepossessed as she was in favor of Quentin, could not think of marrying a common blacksmith; so with some insight doubtless into the young man's natural powers, she told him that his suit was hopeless unless he could transform himself from a blacksmith into a artist, and excel the rival whom her father favored.

It was this that made an artist of Quentin Matsys. From locks and bars he turned himself, first of all, to decorative iron-work, and constructed for the well of the great church of Antwerp, and for the College of Louvain, specimens of such work which gained him great praise for the remarkable delicacy of execution and chasteness of ornamentation which they displayed. His next task was to make a series of exquisitely modeled images of the saints for distribution amongst the people on the occasion of a festival of the Roman Catholic Church, and so much were these admired that they increased his fame considerably. Still, this was not sufficient for the proud painter whose daughter Quentin loved with such an ardent devotion: Quentin was only a worker in iron after all. The "blacksmith of Antwerp" did not despair, however, for, though he was in delicate health, and as yet did not see clearly what was to be done to gain the chief

desire of his life, the artistic instinct was strong enough within him to give him hope. For a time, therefore, he shut himself up, and studied the art of painting with so much diligence that it was not long before he produced a work which he considered worthy of being shown to the father of the young lady with whom he was in love. He took it to him, and the father was so delighted with the painting, that he there and then withdrew all objection to the proposed marriage, and in due course Quentin Matsys and the painter's daughter became man and wife. Many of his artistic productions in iron and on canvas remain to this day in the art collections of Europe to give their testimony to the leading influence in the life of this remarkable man, the influence of a pure and simple love.

Crompton fell in love with a comely young woman of his own station because of her expertness as a spinner on Hargreaves's jenny, and when they set up house together in the little cottage attached to the "Hall i' th' Wood," she afforded him her affectionate aid in working out the models of his famous "mule." Brindley did not fall in love until he was nearly fifty. His biographer spoke of him as having "little time for friendship, and still less for courtship." But at the house of John Henshall, the land surveyor at Bent, near New Chapel, he found a young lady (Henshall's daughter Anne) whose presence was so pleasing to him that he generally took her a pocketful of gingerbread when he visited her father's house. He ultimately proposed to her and was accepted, and they were married, she being nineteen, he forty-nine. Dr. Smiles suggests that "the union may have been quite as much a matter of convenience as of love on his part." After the marriage she managed all his correspondence, and proved herself a "most clever, useful, and affectionate partner."

George Stephenson was too busy a man to have much time for love-making; he was practical in this as in other affairs, and did not go far afield for his choosing. It was while at Black Callerton, fulfilling the duties of brakeman at the Dolly pit, that the idea of marriage seems to have occurred to him as an advisable step; and as an advance of his earnestness in the matter, when once he had made up his mind, it need only be mentioned that he made three proposals of marriage in one year. He was at that time lodging in the farmhouse of Thomas Thompson. Miss Hindmarsh, a farmer's daughter, was the first damsel he made an offer to, and she accepted him; but the farmer would not hear of it, and sent the young engineer about his business. A brakeman with about a pound a week was not considered good enough for the farmer's daughter by any one except herself, and "northern farmers" had in those days a way of enforcing obedience upon their offspring which was effective, if a little rough.

George was doubtless disappointed at being snubbed by the farmer, but he did not fret; he simply "made up" to another young lady, or rather, to two, and tackled the matter in a fair business spirit. There was a servant-girl named Fanny Henderson, living in a farmhouse in which Stephenson lodged, with whom he was on terms of friendliness. Fanny had several sisters, who visited her from time to time, and it was with one of these (sister Ann, in fact) that George next fell in love. It was for Ann (wrote Mr. Pattison, her nephew) that George mended the shoes which Dr. Smiles refers to as having been carried about in the brakeman's pocket on the Sunday afternoon after they were finished, when George every now and then pulled them out and held them up, exclaiming, "What a capital job he had made of them!" Ann Henderson was, we are told, the youngest and prettiest of the sisters; but she was not at all smitten with the amateur shoemaker and jack-of-all-trades, so George, determined to go no further in his love quest than this family circle would take him, at last proposed to the faithful and industrious Fanny, not at all held back by the fact that she was twelve years his senior. There was no "lang coortin'" to follow. After his removal to Willington Quay, to take charge of the engine on Willington Ballast Hill, at an increased wage, he, on the 28th of November, 1802, married Fannie Henderson at Newburn Church. The age of the bride was thirty-three; that of the bridegroom

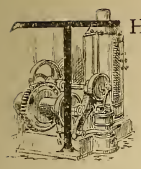
twenty-one. It is worthy of note that the future author of railway traveling had to be content to make the bridal journey in the most primitive of fashions. "Two farm horses," says his biographer, "borrowed from a neighboring farmer, were each provided with a saddle and pillion, and George having mounted one, his wife seated herself behind him, holding on by his waist. The bridesman and bridesmaid in like manner mounted the other horse ; and in this wise the wedding party rode across the country, passing through the old streets of Newcastle, and then by Wallsend to Willington Quay, a ride of about fifteen miles." Fanny made George an affectionate wife, and the two lived happily together for the few years of their married life. George's only son, Robert, who was destined to almost equal his father in fame, was born in October, 1803, and in 1806, shortly after giving birth to a daughter, the devoted wife died, and "George felt as one that had thenceforth to tread the journey of life alone." And for fourteen years George Stephenson remained a widower, happy in the affection of his son, and occupied year by year with increasing business responsibilities ; but in 1820, when fortune was beginning to smile upon him, he again proposed for the hand of his first love, Elizabeth Hindmarsh, the farmer's daughter, and this time no objection was raised to the alliance, and the couple were married at Newburn Church on the 29th of March, 1820. There has been much written concerning George Stephenson's life from 1820 down to the period of his death in 1848 ; but hardly a single glimpse are we permitted to have of the domestic side of his career during those twenty-eight years.

James Nasmyth, the inventor of the steam-hammer, relates, in his autobiography, the story of his falling in love, and for once we get a touch of the romantic in an inventor's loving. After confessing that he had had "few opportunities of enjoying the society of young ladies," he goes on to say, "I had occasion to make a business journey to Sheffield on the 2d of March, 1838, and also to attend on some affairs of a similar character at York. As soon as I had completed my engagement at Sheffield, I had to wait for more than two dreary hours in momentary expectation of the arrival of the coach that was to take me on to York. The coach had been delayed by a deep fall of snow, and was consequently late. When it arrived, I found that there was only one outside place vacant, so I mounted to my seat. It was a very dreary afternoon, and the snow was constantly falling. As we approached Barnsley, I observed, in the remaining murky light of the evening, the blaze of some ironwork furnaces near at hand. On inquiring whose works they were, I was informed that they belonged to Earl Fitzwilliam, and that they were under the management of a Mr. Hartop. The mention of his name, coupled with the sight of the ironworks, brought to my recollection a kind invitation which Mr. Hartop had given me while visiting my workshop in Manchester to order some machine tools, that if I ever happened to be in his neighborhood, he would be most happy to show me anything that was interesting about the ironworks and colliery machinery under his management. I at once decided to terminate my dreary ride on the top of the coach. I descended, and, with my small valise in hand, I trudged over some trackless, snow-covered fields, and made my way by the shortest cut toward the blazing iron furnaces." He was introduced to Mr. Hartop's wife and daughter Anne. Speaking of the latter Mr. Nasmyth says, "I soon perceived in her, most happily and attractively combined, all the conditions that I could hope for and desire to meet with in the dear partner of my existence." He proposed, and was accepted, and two years afterwards, on the 16th of June, 1840, they were married. "From that day to this," he adds, "the course of our united hearts and lives has continued to run on with steady, uninterrupted harmony and mutual happiness. Forty-two years of our married life find us the same affectionate and devoted 'cronies' that we were at the beginning, and there is every prospect that, under God's blessing, we shall continue so to the end."

It is not, however, in their loves that the great inventors have revealed the most romantic features of their lives.

RED-HOT FURNACE CROWN EXPERIMENTS.*

By Chief Engineer F. G. McKean, U.S.N.



THE technical journals a few months ago detailed certain experiments in England from which it was inferred that, as far as they had been carried, turning on the feed would be the best thing to do in the majority of cases when water is low in the boiler.

As the writer has seen no objection raised to this conclusion, except some deprecatory observations by the distinguished experimenters themselves, he would suggest that, whatever may be the case with the Lancashire boilers fitted with dispersion pipes in what becomes the steam space as soon as the water-level begins to fall, until experiments have been made with marine or other boilers which necessarily introduce the feed at a much lower level, we had better not act upon this inference.

The belief among most old engineers has been, that to start the feed into a boiler in which the water has become low for a sufficient length of time, would almost inevitably produce explosion, and the labors of the committee above alluded to do not seem entirely to controvert the old belief, though the experimenters may be correct in the inference that such explosions were not always due to the red-hot crown sheets. The reasons for only partial agreement with the deductions are the following:

1. When the experimenters declare that their boiler did not explode, we have no difficulty in admitting the fact, because we are told at the same time that the pressure fell in every instance in which the safety-valves were kept open. The committee neglected to remind us why the pressure fell, and therein consists a vast difference between their special arrangements and those which obtain in marine and other practice. Owing to the high position of the feed-pipes, the experiments simply instituted a simultaneous struggle between two steam-producing furnaces acting with comparative slowness in the lower half of a boiler, and a steam-annihilating jet condenser acting rapidly in the upper half. The condenser was sure to win unless it was absurdly small, and its winning was doubly assured in this case by the pump confessedly supplying water enough for two or four boilers of the same size.

On the other hand, some old engineers will continue to believe, for the present at least, that while in actual service, in the majority of cases when the the water is low, the feed would be introduced, if at all, near the bottom of the boiler, or at least below the actual as well as normal water-level, and, being cold, would remain there, displacing the boiler-water already on the point of becoming steam: then lifting the latter, which would have a temperature of 230° and upward, instead of from 44° to 62°, over the heated surfaces, which nowadays would be of steel instead of iron, and doing it slowly and without deluging them, the hot water would generate steam with more than normal rapidity until the weakest part of the boiler would give way in consequence of the increasing pressure, and half a dozen separate events would follow like flashes of lightning—as that genius, Zerah Colburn, explained—and the boiler would burst. The two cases are in several points distinct; let us avoid drawing universal deductions from either.

The reason for using so large a pump was theoretically excellent, as was also the reason for avoiding, near a public thoroughfare, the explosion which it was the ostensible object of the tests to risk, but practically the former vitiated the experiments by intensifying the action of the *quasi* jet condenser, while the latter, together with other reasons, involved working with raised safety-valves in all the experiments after 1*a*, a state of affairs which, to some extent, vitiates the con-

* Journal of American Society of Naval Engineers.

clusion, as we will endeavor to show presently.

2. The report lays great and repeated stress upon the steam beginning to fall in all the experiments with raised safety-valves immediately upon the feed being admitted, but it passes more lightly over the fact that in the only trial with closed valves the pressure rose 21 pounds in ¾-minute. If the initial pressure, instead of being kept down to 6 pounds in this experiment, had been the normal for starting the engines, and 21 pounds had been added, to all intents and purposes instantaneously, the consequences might have been different in the experimental case, and would be so in many practical ones. Perhaps the observers, apart from the reasons given, and quite unintentionally, showed a certain consideration for their boiler when they carried out all subsequent trials with both safety-valves blowing "hard," "freely," "fiercely," etc.

Before leaving the matter of safety-valves, it is suggested that while the continuous escape of steam may be considered equivalent to its continuous flow toward an engine in motion, there are many cases in marine, and especially naval practice, in which short stoppages are made with spread fires, or the fires kept banked for days together, with steam perhaps near the "top notch"; and in shop practice fires are often kept banked six nights in a week with safety-valves down, *i.e.*, under circumstances similar to, but (with a leaky boiler and higher steam) more dangerous than those detailed in experiment. It may also be suggested that if further trials are made the outflow from the safety-valves, if they must be raised, deserves to be narrowly watched. In this experiment 1 it was intended that both valves should be shut, but by an oversight one was left open. It seems as if the escape of steam from that one should have indicated (*a*) a partial instantaneous fall of pressure, due to the partial vacuum around the sixty-four sprays of injection water, and which the length and small bore of the steam gage connections possibly made that instrument too sluggish to record; (*b*) an instantaneous rise of pressure, which the same sluggish records modified into an increase of only 6 pounds in 1¼ minutes, and (*c*) the self-evident, gradual fall of pressure as the steam was partly condensed and partly blown off.

3. The report implies in one place that it is hardly possible that explosions have been caused by pumping cold water on red-hot crown sheets, because the latter would have been rent, whereas in most cases the shell has given way. But this is an assumption. If the smaller, thinner, perhaps more perfectly circular cylinder with fewer joints and parts, happens to be more elastic or stronger than the larger, thicker shell built up of many parts, the former may stand in spite of overheating, and the latter may rend; while, if the water assumes the spheroidal state, it may be abnormally heated without, at first, being in actual contact with the red-hot plates. It is the pressure which starts the damage in any case, searching out the weakest spots in the whole structure, whether it be some "original malconstruction of the boiler or the dilapidated condition into which it has been allowed to fall," so that if the pressure is due in part to some other cause, the overheating of the plates may become of secondary importance, as, indeed, the committee implies in its allusion to the small specific heat of iron as compared with water. For "crown sheets" the marine engineer would probably prefer to read "top of back connection," for with really red-hot crown sheets he would most likely have heard previously from the tubes.

This may be a suitable place for allusion to the "ungovernable" pressure and the "instantaneous disengagement of an immense volume of steam," for which the committee has scorn and disbelief, though their steam-gage indicated a decided tendency in that direction. In Zerah Colburn's theory of violent explosions one step was the momentary relief of pressure from the surface of the boiler-water, due more particularly to a leak in the case he was considering; and he argued that when this occurred the surface boiler-water, having a higher temperature than was due to the pressure, flashed into steam. One experiment seems to corroborate this view, if we concede a partial vacuum due to the jets, followed by the instant conversion

of the layer of abnormally heated surface-water into steam of some unknown pressure of which the gage had time only to note a 21-pound rise, the further ascent being overpowered partly by the pump and partly by that very pressure again raising the boiling-point above what was necessary for producing more steam. In the case of a rent in the boiler—and in practice that might have ensued from a typical 21-pound rise—all the boiler-water should theoretically have flashed into "ungovernable" steam; in the experiment it seems apparent why it did not. Critics who will not admit that a partial vacuum could have existed in any part of the boiler at any instant during the experiments 1 and 1*a*, causing the disengagement of a large volume of steam (because that should imply a greater supposable vacuum in the experiments with raised safety-valves, due to the double action of an annihilation and a release of steam), must explain (*a*) how a number of small streams of cold water can be injected into a large body of steam without condensing at least a part; (*b*) how steam can be condensed without forming an appreciable vacuum, and (*c*) if a partial and momentary vacuum *was* formed, why the unnoted entry of air at the same time that steam was escaping through the two safety-valves in all the after-experiments might not have assisted the newly-forming steam to destroy that vacuum so quickly that the gage was not affected at all in those trials, while it was measurably affected as to the rise of pressure in the first two.

We can infer that the crown sheets were decidedly hot in all the experiments, though perhaps not positively red hot in more than one-half of them, and this brings up another point. In trials 1 and 1*a* there was low water "and no mistake," for it was blown down to 16 inches below the crowns; while in the timed experiments the water was evaporated off more slowly, so that its lowest level was about 2¾ inches below the crowns; it is a question if, in all of these later trials, a strip of metal on each side of the apex may not have carried off so much of the heat from the crown to the water below by conduction as to have lessened the effect of the red heat, and in some cases annulled it altogether. In the timed experiments the jet-action of the feed was limited, for it ceased as soon as the boiler-water reached the level of the spring openings, and the red heat, when it existed, was confined to a narrow strip; but the committee found that with unquestionably low water accompanied by greatly increased steam room, and with safety-valves closed, there was a sudden accession of pressure when the feed was turned on. Now, whether that accession is attributable to a phase of Colburn's theory or to the exposure of a greater extent of furnace sheet, the rise of steam is certain, and throws a serious doubt upon the conclusion that in the majority of cases, with low water, turning on the feed seems to be the best thing to do, for it would appear to depend upon how "low" the water is, and we knew that before.

In another part of the report, however, it is acknowledged that perhaps one explosion in six does occur from pumping water upon red-hot crown sheets; also that nearly all explosions in confined spaces (which would include those on board a ship) are fatal; and still it is suggested that turning on the feed would possibly be the best thing to do with low water! The information that there are six chances to one in our favor is a novel application of the factor of safety, and not yet sufficiently reassuring, we think, to make the practice universal.

The spheroidal condition of water has been alluded to by the experimenters, in one trial, for they say that the feed was continued until the plates had passed from red heat to the temperature of water in the boiler. This is true, but in the account of that trial, No. 7, it is also stated that with two safety-valves blowing "fiercely" and "freely," and with injection enough to "feed" two boilers, the pressure at one stage of this experiment only yielded at the rate of one pound per minute, insomuch that the valves were raised further by hand. Limiting our consideration to the question of pressure alone, suppose the safety-valves seated, and only one ordinary feed, might not, nay, would not, the pressure have gone up? Then suppose the instantaneous and possibly "ungov-

ernable" addition of some unknown pressure analogous to the 21 pounds noted above, might not the boiler have "gone up," too?

The published conclusions from the experiments can hardly fail to be dangerous, for the average water-tender who hears of them, not laying sufficient stress upon the declared doubts and cautions of the committee, will probably draw the inference that low water is a comparatively trifling matter; his induced carelessness will therefore be likely to bring it about, and when he finds himself confronted with it, he will probably turn on the feed with a light heart, regardless of time and circumstances, and, in the absence of sufficient injection-roses, pumping-power, and safety-valves, disaster may be expected to follow in the future as in the past; for the implication in the report that because certain selected explosions specified were not caused by low water, therefore low water causes next to none, is a *non sequitur*, further based upon the possible fallacy that the hottest part of the boiler is necessarily, always and for that reason, the weakest part, and that crown sheets are the sole source of risk when the water has become low and feed is pumped into a boiler.

Finally, it is suggested that while the profession at large owes most cordial thanks to the committee for the time and trouble which they have taken, and the expense incurred, and should hope that the matter will not be allowed to rest under the slightest uncertainty, the experiments alluded to were not made under circumstances of universal application; that the sweeping inference drawn from them is misleading and dangerous, and that until the question is decided more fully the marine engineer at least had better not "reinvigorate" with cold water the possibly hot steel plates of a boiler in service, even with the odds of six to one in his favor, or he may bring about an explosion without having the shelter afforded by a barricade.

COAL AND COMBUSTION.

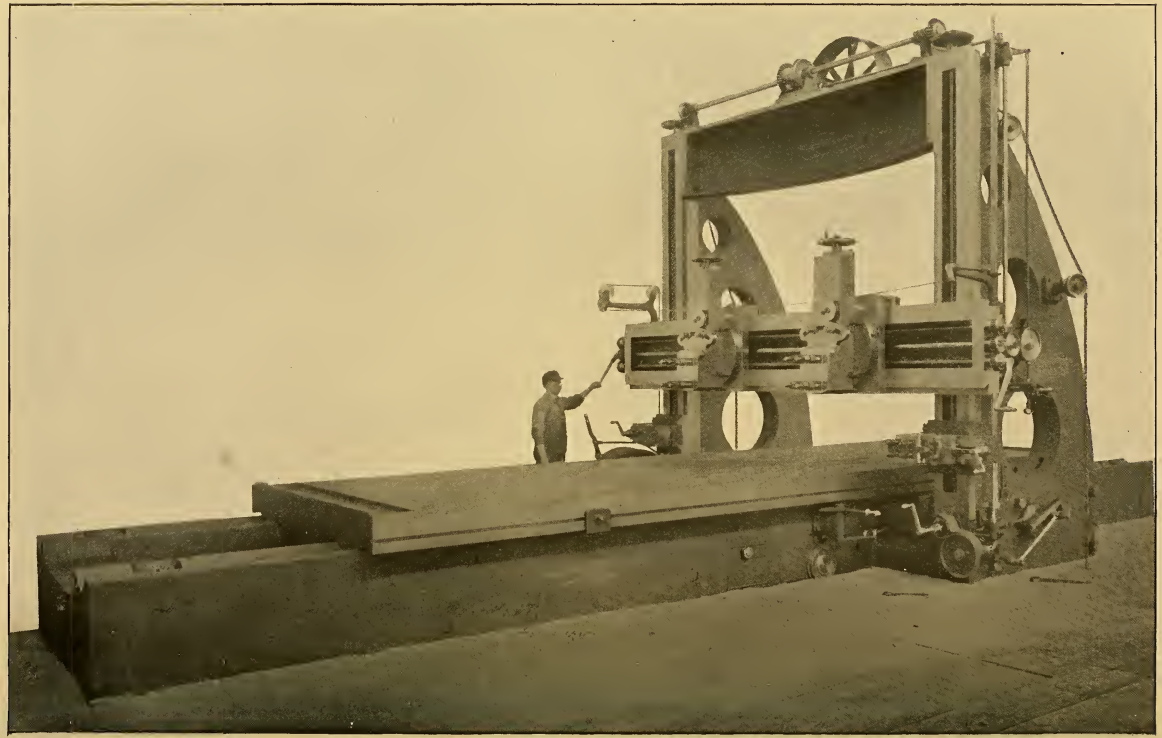
MR. B. HOLGATE, F.G.S., recently delivered a lecture before the members of the Yorkshire (England) College Engineering Society on "The Behavior of Different Kinds of Coal during Combustion." In another part of this magazine, Mr. William Kent gives some very interesting facts on this subject. *Iron*, of London, in its report of the lecture, said Mr. Holgate wished to show them first the different conditions under which coals were used, then how these coals were formed, and to describe them as they found them, after which he hoped to be able to point out why some of these coals were better suited for certain purposes than others were. On a house fire almost any kind of coal would burn, and beyond the fact that some kinds gave off more smoke than others they did not observe much peculiarity about them. But as soon as they wanted to make something particular with these coals they found they had a very complex material to deal with. Unfortunately, too, they had to take coal as they found it, and make the best of it. Collieries could not make coal to suit them, and they must go to the colliery where the coal answered their purposes best. Having described the processes which coal underwent in gasmaking in the Siemens and reverberatory furnaces and in a house fire, he went on to say that coal was either of animal or vegetable origin. Some coal contained a large amount of animal matter, and the cannel coal from which oil was made was formed entirely of shellfish. In other coals they found a comparatively large amount of fish remains, such as the cannel coal used at Leeds Gas-works, and which gave the gas its high illuminating power. That coal contained a considerable amount of fish remains, and the coke from it came out of the retort exactly the same in shape as it went in. Cannel coals were deposited not on dry land, but under water. He

described the other kinds of coal, and pointed out that though they differed widely in appearance and characteristics, they were all pretty nearly the same in their chemical composition, and that therefore chemical analysis would not assist them very much in determining their burning qualities. They could, however, by experience, judge by the appearance of the coal what it was best suited for. The better bed coal was dull and black in appearance, and when scratched it gave a brown streak. It was almost valueless when burned at a low temperature, such as in a house fire. In a boiler furnace it behaved better, though it required a great draught; and it was seen to best advantage when burned at a very high temperature. The hards of the Middleton Little coal did not give off gas so readily as the other, but it was delivered more readily, and in greater abundance. Indeed, they found that coals having, as he had said, pretty nearly the same chemical constitution, but differing in the distances between their places of cleavage, gave totally different results during combustion. Thus coals which broke naturally into small would deliver their gas more slowly; and the gas not clearing its way so readily as it would if the pieces were larger, they would get less gas from them. Beeston Bed coal broke into fairly large pieces, and Belgian coal, owing to the contortion to which the beds had been subjected, was very much shattered. After dealing at length with anthracite and coking coals, and pointing out that coals which were very soft and broke easily into small made the hardest and most valuable coke, he touched on the subject of smoke. If coals were thrown on very small and in large quantities the gases and the finely divided solid matter were given off at a temperature so low that it did not burn, and this caused a dense yellow smoke, which was sheer waste. But, on the other hand, there was another kind of smoke, black in color, which was the result of the flame impinging against the (comparatively) cold boiler-plate, and which was not a wasteful smoke. In conclusion, Mr. Holgate said it was possible to burn smoke and get greater heat out of it, but many people would prefer to save the expense and not consume their smoke, even though they ran the risk of being fined occasionally. He sometimes found that it was cheaper in many ways to use round coal than small, for it did not take so much throwing on or raking out, nor was there so much rubbish to cart away. A lengthy and interesting discussion followed, in the course of which Mr. Ambler (smoke inspector) cited a case where a firm saved £2000 a year by using small coal, employing a mechanical stoker, and consuming the smoke. Professor Goodman said that flaming coal was the best for obtaining heat, but wherever there was black smoke there was waste in the shape of the carbon-monoxide which was given off with it.

CROSS-COMPOUND CORLISS ENGINES.

THE engraving printed on page 232 shows a cross-compound Corliss engine which has just been built by the Frick Company, engineers, Waynesboro, Pa. Where the size of the engine-room will permit it, this form of the compound engine appears to be more desirable than one constructed in tandem style, although so far as economy of fuel is concerned there should be no difference.

The engraving of this engine, which was made by A. P. Norman, shows the construction of these engines so clearly that the reader can readily see in what particulars it differs from other engines of this class, without any lengthy description. The cranks are coupled to the shaft at right angles, and the governor is connected with the valve-gear on both the high- and low-pressure cylinders, although independent hand adjustment is provided for the low-pressure cylinder. For large plants, where a uniform amount of power is desired, the compound Corliss engine is meeting with great approval, for repeated tests of such engines show their great economy. As soon as tests of the engines illustrated have been made, a report of the same will be published, with such further details as may be of interest.



TEN-FOOT PLANING MACHINE, BUILT BY THE NILES TOOL WORKS, HAMILTON, O.

A TEN-FOOT PLANING MACHINE.

THE illustration on the opposite page is of a 10-foot planing machine built by the Niles Tool Works, of Hamilton, O. This machine will plane 10 feet wide and 10 feet high, and is provided with four tool-heads, two on the cross-rail and one on each of the housings.

Housings are of double-web form and extend down to the foundation. Cross-rail has a depth on face of 27¼ inches and is 22 inches deep in center from front to back. It is cored out in box-girder form, making it very rigid. One end of rail is extended so as to allow one of the heads to be fed across the entire width of machine.

The bed is double-webbed on the sides and thoroughly braced by box-girder construction throughout its entire length. Between the housings it is tied together in box form, making it exceptionally stiff at the point of greatest strain.

The table is 90 inches wide, 12 inches deep over the ways, and 9 inches deep at the sides. It is strongly ribbed crosswise at intervals of 24 inches. At proper intervals in each of the ways self-lubricating rollers of brass are placed which keep the bed and table-ways thoroughly oiled.

Driving-pulley communicates motion to the driving pinion through tangent gearing, the worm being double pitch. Worm and worm wheel are enclosed in a tight casting to allow worm to run in a bath of oil.

Belts are shifted by a patent automatic device which transfers but one belt at a time, preventing the two belts from coming in contact with the tight pulley at the same time. It is entirely disconnected from the feeding apparatus and gives the operator quick and easy control over the motion of the table without using the countershaft shipper.

Driving-pulleys and gearing are placed on the side of the machine opposite the workman, entirely out of the way, but still completely under control from his usual position.

The feeds are automatic in all directions. They are operated by a patent feeding device which renders them absolutely positive. This feeding device is noted for its uniformity in action, and requires no power whatever except at the actual moment of feeding. Feed mechanism for the side-heads is entirely independent of the elevating screws; hence the rail can be raised or lowered without disconnecting the feed.

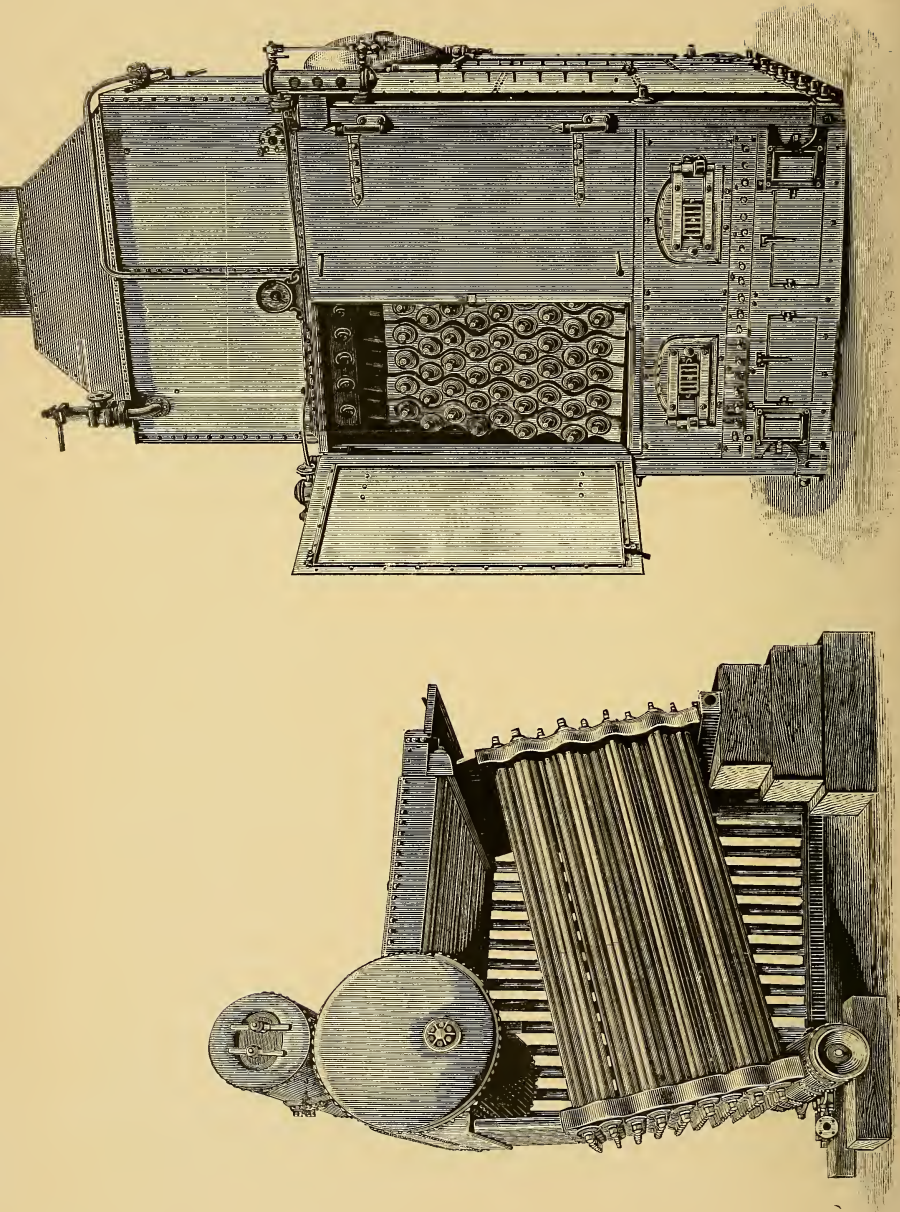
The machine is practically noiseless in operation; it shifts quietly and reverses without shock.

All gearing is accurately cut from the solid. Shafts are heavy steel forgings, sufficiently large to prevent torsion, and run bearings of best gun metal.

The tool-aprons are provided with a relief attachment which automatically lifts the tools clear of work on the back-stroke. A fair conception of the massiveness of this machine may be had from the fact that the belt is geared to the table in ratio to give a net power on the tools of 20,000 pounds.

NEW MARINE BOILERS.

ON the following two pages are shown illustrations of a new marine boiler on the water-tube principle, which the Babcock & Wilcox Company are introducing, and which they recently exhibited at Chelsea, England, in the grounds of the Royal Naval Exhibition. It is designed on the same principle as their now well-known land boiler, the chief alteration consisting in the adoption of smaller tubes and of vertical tubes at the sides in place of the brickwork in which their land type of boiler is inclosed. *Engineering*, of London, described this boiler as follows: In place of each of the 4-

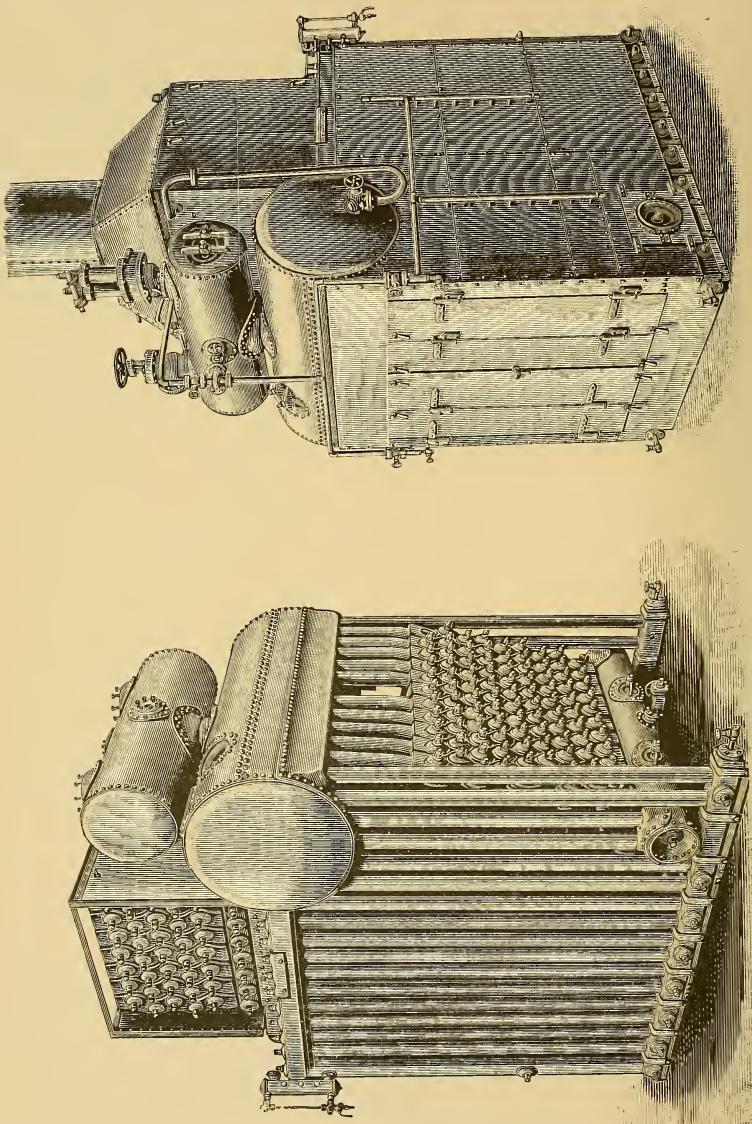


NEW WATER-TUBE MARINE BOILER. BUILT BY THE BABCOCK & WILCOX COMPANY.

inch inclined tubes which form the bulk of the heating surface, there are four 1½-inch tubes. As will be seen, the boiler consists of a series of these inclined tubes passing over the fire. These are expanded at each end into headers of wrought steel. The rear headers are connected to the steam and water drum by short vertical tubes. The front headers are connected by nipples with a horizontal water-box which, in turn, is connected to the steam and water drum by a number of horizontal tubes. Above the latter is a feed-water heater, which consists of a series of tubes expanded into headers at each end in the same manner as the boiler proper. Above the main drum and riveted to it is a steam drum, which carries the usual fittings. There is also a series of vertical water tubes at the sides which present additional heating surface and also serve as supports affording rigidity to the whole structure. At the lowest part of the circulating system, which is at the bottom of the rear headers, there is a mud drum to arrest any deposit.

The feed is introduced at the bottom of the feed-water heater, and after passing through the tubes of the latter it leaves it at the top, and passing through a combined stop and check valve enters the boiler proper at the center of the steam and water or main drum. From thence the water descends through the short straight tubes to the rear headers, and then ascends through the inclined tubes into the front headers. Through the latter it rises into the horizontal water-box, and again finds its way into the main drum through the horizontal tubes as shown. The furnace, as will be seen, is immediately under the inclined tubes. The gases ascend around and amongst these tubes, and then pass through the feed-water heater to the chimney. In this way the advantage is obtained of the gases passing at right angles to the axis of the tubes, so that they are in the most favorable position to impart their heat to the water. The further advantage is secured of the hottest gases being brought in contact with the water in the boiler proper, which is at the highest temperature, whilst the partially spent gases have their remaining heat abstracted by the colder feed in the heater. The circulation of water in the vertical water tubes at the side is practically independent of that in the inclined tubes; although at the same time all are connected to the main drum. It should be stated that at the front end of the boiler, in place of side vertical tubes, there are two vertical boxes of rectangular section. These are connected by a cross-box, also of rectangular section, which is above the doors. They are utilized to carry the doors, etc., as will be seen by the engraving showing the front view. The sides of the boiler are suitably inclosed by a non-conducting material covered by a thin sheet-iron casing. It may be mentioned that there are no screwed joints throughout, the tubes being all expanded, and where connection has to be made between square sections it is done by means of nipples. There are no joints exposed to the action of the fire; nor are there any flat surfaces requiring stays. All the tubes are of lap-welded wrought iron, and the drums are of mild steel plate, the holes being drilled in place and the rivets closed by hydraulic pressure. It will be easily understood that for the economical construction of such a boiler as this a special plant is required, and the Babcock & Wilcox Company have recently laid down several specially designed machine tools, all worked by hydraulic pressure. Some of these are of a very ingenious and novel description; for instance, the machinery for shaping, welding, and staggering the rectangular section headers is of a most interesting kind.

The Babcock & Wilcox boiler naturally has the usual advantages common to all water-tube boilers. The main point, that of water circulation, appears to be well provided for. The water, in the course of circulation, is divided up so that it will absorb the heat readily, the whole in turn passing over the hottest part of the heating surface. This arrangement insures two good features, namely, that it enables steam to be raised very rapidly in an emergency, and it also gives an almost equal temperature throughout the boiler; thus avoiding the great strains due to unequal expansion to which the ordinary type of marine boiler is so subject. The advan-



NEW WATER-TUBE MARINE BOILER, BUILT BY THE BABCOCK & WILCOX COMPANY.

tages of only thin metal separating the water from the gases will be apparent, especially in connection with the fact that there are no tube-plates to give trouble as in an ordinary boiler.

This boiler has already been fitted into several vessels, and has given general satisfaction. It is said to occupy much less space, and to weigh less, power for power, than the ordinary marine boiler. Hand-holes are provided at the ends of the tubes for inspection and cleaning, and blow-off cocks are fitted at the mud drum and bottom boxes. On each side of the boiler and on the heater there is a blow-pipe apparatus, by means of which jets of steam may be directed across the tube surfaces to free them of any soot which may be deposited thereon. We annex the particulars of a test made with this boiler before leaving the works at Kilbowie, near Glasgow. It should be stated, however, that this trial was only of a preliminary nature, and although the records given are put forward as strictly accurate, they do not in the opinion of the manufacturers represent the best performance of the boiler. There was a difficulty in getting the gage glasses to stand, otherwise an average pressure of 200 pounds would have been carried. A more complete test is to be made, of which we hope to publish full details.

Heating surface	1669 sq. ft.
Grate surface (6 ft. 2 in. long by 6 ft. 8 in. wide)	41.66 "
Ratio of heating to grate surface	40.6
Kind of fuel used	Nixon's Navigation
Duration of test	5 hours
Average observed gage pressure	150 lbs.
Average temperature of water fed to the boiler through heater	180°
Average temperature of water supplied to the heater	43°
Pounds of coal fired	4500 lbs.
Pounds of refuse	236 "
Moisture, .87 per cent	39 "
Pounds of combustible	4175 "
Per cent. of ashes	6.36 per cent.
Coal consumed per square foot of grate per hour	21.6 lbs.
Total water evaporated	37,492 "
Water evaporated per hour	7498.4 "
Water evaporated per square foot heating surface per hour	4.492 "
Water evaporated per pound of coal; conditions, feed-water 43° F., steam pressure 150 pounds	8.331 "
Water evaporated per pound of coal, assuming feed-water at 212°, and under atmospheric pressure	10.194 "
Water evaporated per pound of combustible; actual conditions, feed-water 43° F., steam pressure 150 pounds	8.98 "
Water evaporated per pound of combustible; assuming feed-water at 212° and under atmospheric pressure	10.99 "
Quality of steam	Dry by touch and sight.
Horse power developed	{ Assuming 15 lbs. water per H.P. hour = 500 H.P.
Temperature of boiler-room	45°.
" of flue gases	560° to 670°.
Force of draught in inches of water	in .25.

[This test, as will be seen, shows a remarkably high efficiency, perhaps more than could be obtained in actual practice with a pressure of 150 pounds. The fuel used, we understand, was carefully selected Scotch coal, so that the best possible results were obtained. If, however, the pressure of 200 pounds, for which the boiler was designed, had been carried, a still higher efficiency would have been shown, so that while this test with selected coal is extremely good, in actual practice, carrying the higher pressure, the results would probably be even better than the above would indicate.—ED. CASSIER'S MAGAZINE].

THE NUMBER OF NEW MILLS.

IT is interesting to note the rate of development of our manufacturing industries, and to study the effect of different causes which may hasten or retard their growth, says the *Textile Manufacturing World.* At the present time the action of the McKinley tariff is eagerly watched upon every line of industry which it affects, and the establishment noted of new enterprises, which might be supposed to be more or less influenced by its provisions for their protection, or otherwise.

In looking into this matter with a view of comparing the number of new mills, established during the first nine months of the years 1890 and 1891 respectively, we find the subject of considerable importance. We do not claim that the data here given are absolutely correct, but we believe they are the most complete and exhaustive of any that have yet been published on this subject, as we keep a systematic record of new mills projected and undertaken, for the compliation of which we draw upon every source obtainable for information. We believe that there are comparatively few new mills which reach completion without our knowledge.

We have been careful in making these data to include only such enterprises as have really materialized, and have omitted scores of projected schemes for new mills which have never advanced further than the stage of incorporation.

We have not yet carried investigations to the point of determining the capacity of these new mills, and figures given below simply represent the number of such enterprises, without regard to their productive capacity. This, of course, gives little information as to the comparative growth of the *productive ca-*

TABLE NO. I.

	1890				1891					
	Cotton.	Woolen.	Knit.	Silk.	Cotton.	Woolen.	Knit.	Silk.	Plush.	Linen
Maine	3	2			1	4			1	
New Hamphire		1	2		2	1	1			
Vermont					1	1	2			
Massachusetts	9	6	4		13	8	5		2	
Rhode Island	3		2		2	1	2			
Connecticut	2	1		5	4	1	2		2	
New York		4	12	3	1	3	21	1	3	
New Jersey		1		8	1	2	4	1	2	
Pennsylvania		10	2	5	3	9	19		2	
Delaware							1			
Maryland		1	1				1			
Virginia	1	3	6			1	2			
West Virginia		1	2							
North Carolina	8		3		6		1			
South Carolina	9				7		1			
Georgia	5	1	3		1		1			
Alabama	6		2		4					
Mississippi	1						1			
Louisiana	1		1				1			
Texas	2	1	1		2	1				
Tennessee		1				1	1			
Arkansas	1									
Kentucky	1	1				2				
Ohio	1					1	1			
Indiana		2	1				2			
Illinios		3	3		1	1	3			
Michigan							1			
Wisconsin			1			2	1			1
Minnesota		1				1	1			1
Iowa						1	1			
Missouri		1			1	1				
Kansas			1							
Colorado		1			1					
Utah							1			
Nevada										
Idaho						1				
Oregon							1			
Total	53	23	47	21	51	43	78	2	12	1

bacity of the textile industries for the periods mentioned, but it does give an indication of *comparative activity*, and admits of comparisons which are interesting.

It will be noticed that the number of new cotton- and new woolen-mills is singularly enough just about the same for the corresponding periods of each year, but the number of knitting-mills in 1891 shows the great increase in activity in this branch of the trade. The figures in the silk column show plainly enough that there has been no encouragement for new enterprises in this direction, while twelve new plush-mills and two new linen-mills are gratifying evidence of the stimulation offered by the McKinley tariff to these branches of the trade.

If we proceed further and analyze the growth of the industries in different sections of the country, we find that among the cotton-mills the increase in the South was much larger in 1890 than in 1891. This of course is due to the industrial activity in that section at that time, which has since subsided to a great extent. In the North, however, we find just the reverse state of affairs, for whereas there were but 18 new cotton-mills projected in the first nine months of 1890, 31 is the number to its credit for the corresponding period in 1891.

TABLE NO. II.

	South		North	
	1890.	1891.	1890.	1891.
Cotton	35	21	18	21
Woolen	9	5	34	38
Knit	19	9	28	69
Silk	.....	.....	21	2
Plush	.....	.....	.....	12
Linen	.....	.....	.....	2
Total	63	35	101	154

In the division of North and South we have included the Western States among the Northern mills. In both the woolen and knitting industries we find that the South has fallen off materially while the Northern States have gained, the gain in the woolen industry being slight, while the number of new knitting-mills is more than doubled.

Another interesting feature of the question is the consideration of the character of the new mills. This does not appear in the first table, but in preparing these data we made a still further classification, dividing the mills into two groups, viz: those built by new companies formed for the purpose, and those built by existing companies already operating mills, to whose plant the new mills would be an addition. Considerable judgment was necessary in the case of the latter group, and we have been careful not to count as a new mill any slight addition to the plant which would be simply an increase in one or more of its departments, and have counted it only in the case of an addition which could properly be dignified by the name of mill, and in most cases these are separate and complete establishments. The table is as follows:

TABLE NO. III.

	New Mills Built by New Companies.		New Mills Built by Old Companies.	
	1890.	1891.	1890.	1891.
Cotton	29	26	24	26
Woolen	16	16	27	27
Knit	35	35	12	23
Silk	12	1	9	.....
Plush	.....	10	.....	2
Linen	.....	1	.....	1
Total	92	109	72	79

Most of the new mills projected by new companies in the year 1890 were in the South, while in 1891, with the exception of the cotton industry, the new companies are most numerous in the North. As would be natural to suppose, the new mills built by existing companies have been generally located in the North.

In 1890 we find Massachussetts and New York lead in a number of new mills, each having 19 to their credit, Pennsylvania follows with 17, while North Carolina follows with 11.

In 1891 Pennsylvania carries off the honors as a mill-building State, with 33 as its quota. It must be stated, however, that the majority of these are knitting-mills, many of which are comparatively small concerns. New York ranks second with 29, while Massachusetts follows closely with 28.

The figures show that in the South the States of North Carolina, South Carolina, Georgia, and Alabama have shown most progress.



FREDERICK LUNKENHEIMER.

THE LATE FREDERICK LUNKENHEIMER.

ONE of those who have been foremost in bringing the brass business to such an advanced state in this country, and who may be called one of the pioneers of that branch of the mechanical arts, was the late Frederick Lunkenheimer, who died about two years ago.

He was born on the 24th day of October, 1825, in Ingleheim, in the Rhein District, Germany, and at the schools of his native town he acquired a good elementary education. At the age of fifteen he betook himself to the neighboring city of Mainz, there to learn the elements of mechanics. After he had learned his trade and had served his apprenticeship he came to America. On the 16th of August, 1845, he took passage at Havre and arrived at New York on the 22d of September, after a passage of five weeks, friendless and penniless. He at once found employment in an establishment where the first Morse telegraph instruments were made, and where he remained for about five years, when he turned his steps toward the West. From St. Louis, where he remained for two years, desiring to become acquainted with the South, he made a journey to New Orleans and engaged in various mechanical pursuits in that city, among which was the manufacture of sewing-machine needles, making, it is claimed, the first ones produced in the West.

He also established himself as a silver and nickel plater, doing business on Royal street. In 1854 an epidemic of yellow fever afflicted New Orleans, and Mr. Lunkenheimer was attacked by the dread disease. His then powerful constitution and regular habits stood him in good stead and brought him safely through the illness. This experience, however, caused him to lose any desire to remain longer in the South.

He at first intended to return to the East, but while on his journey North he had the misfortune to be robbed of all his savings of several years. This compelled him to make Cincinnati his goal, in which city he arrived October 24, 1854.

He at once found a position as foreman in Miles Greenwood's foundry, at that time one of the foremost of its kind in the country. This position he held for eight years, giving it up in 1862 only to go into business for himself as a brass founder, with one apprentice as his only assistant. The business was prosperous and grew so quickly that at the end of five years the original workshop had become too small, and he removed to a larger building, employing at this time about 40 men. In a few years even this building had become too limited for the demands of the business, and a larger building was erected on Eighth street, where, in 1880, he removed, and where the business is still carried on by his sons, employing over 200 men. The business has now outgrown even these, and preparations are being made for the erection in the northwestern part of the city of what will be, when completed, one of the largest brass foundries in this country.

At the time when Mr. Lunkenheimer embarked in the brass business most of the brass work for machinery had to be imported from England. This opened a great field for brass goods in the United States, and Mr. Lunkenheimer, being of an inventive turn of mind, soon put his talents to good use, producing what were considered great improvements. Numerous inventions in oil-cups, automatic lubricators, valves, etc., representing some 30 patents, were in his name.

Mr. Lunkenheimer was a man who enjoyed to the fullest degree the esteem of his fellow-citizens. From a simple mechanic by his energy, skill, and honorable dealings he raised himself until he became the possessor of a large and influential business, the products of which have a national reputation.

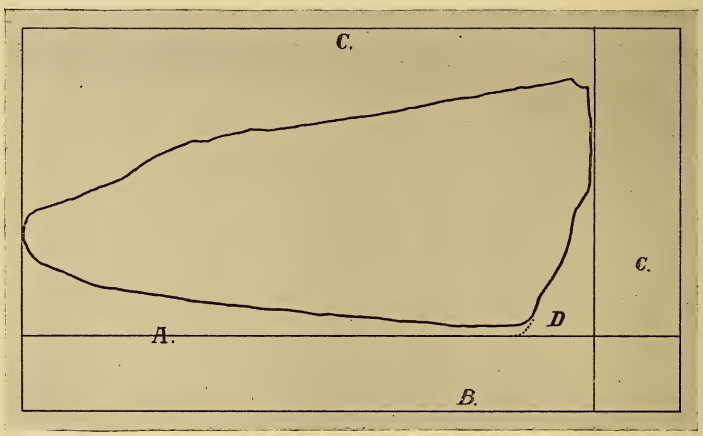
A PROBLEM FOR STATIONARY ENGINEERS.

By Thomas Pray, Jr., C. and C.E.

THE diagram shown on this page was taken from one end of a pair of condensing engines, owned by a city in the United States whose name will not be mentioned, and is a specimen of everyday work of a pumping engine which has been in use nine years, running from ten to fifteen hours on the average each day of the year.

This engine is not called "condensing" as a joke, as one might think to look at the diagram, for the original card sent to the writer is endorsed "Vacuum 23½ inches, throttle open."

In making computations from the diagram, figure from the terminal pressure (38½ pounds absolute) the amount of steam per I.H.P., density being .09304, then suppose the engine



A PECULIAR DIAGRAM TAKEN FROM A CONDENSING ENGINE.

The engine is 12 inches in diameter, 20 inches stroke, running at 155 revolutions per minute, the scale of diagram being 30 per inch.

NOTE.—Recognizing the great importance of a correct understanding of the steam engine indicator both to the engineer and his employer, the publishers of CASSIER'S MAGAZINE have arranged to print a series of problems similar to this one, which they solicit engineers to solve. As an inducement they will give an award of five dollars each for the first two correct solutions which we receive. The conditions require that the answer contain an explanation of the whole computation, together with the figures. The time a letter is posted, as per date on the post-mark of the envelope, will be considered in making the award. The successful answers will be printed together with the names of the winners. No one but an engineer in charge of a steam plant will be entitled to the award. The problems should prove of much value, as they are intended to instruct, not to amuse.—ED.

has done 2700 days' work, 12 hours each. At the rate of H.P. and water per H.P. for all that time as shown by the diagram, the boilers evaporate 8½ pounds of water per pound of coal, which costs $4 per ton of 2000 pounds. What amount of money has it cost the city to run, as indicated by the card, this relic of antiquity over what it would have cost to run a good condensing engine under a guarantee of the builder, say to use not over 22 pounds of water per H.P. per hour, using same coal at the same price per ton.

A being the atmospheric line, sup-

pose the exhaust was on that line, and compression being at the dots D, what is the percentage of loss by back-pressure in H.P. or in per cent of area, either way?

C is clearance, which is a trifle over 15 per cent., and is to be included.

The only factors needed are the cubic inches, or feet of steam, the density of steam, and the correct application of the various terms as given in the data above.

This problem is not theoretical or imaginary, but represents dollars and cents, and computation will show that several thousand dollars would have been saved to the city if a change as suggested had been made nine years ago, during which these engines had been in use. The object of this problem is to let engineers who run such engines (for there are many of them left) figure out what has been done, is doing, and can be done, under different conditions. Of course, as is known, all indicators are mischievous and at times unreliable, but in this case we suppose the diagram represents the actual facts, and make computations from that standpoint.

HOW TO SET UP PUMPS.

I HAVE taken charge of several steam plants after the pumps were set up and connected, and I have had much trouble to take care of them because of their inaccessibility. I have been in many large and small cities, and on visiting engine-rooms in different places I find the same trouble largely prevails. On going into many engine-rooms one of the hard things to find is the steam pump. Whether used for boiler-feeding or fire-protection, it looks as if the engineer or millwright who put up the pump was ashamed of either the machine or his workmanship, as the pump is usually placed in some dark, obscure recess or corner or buried nearly out of sight. It looks as if some man high up in authority had devoted hours of study to solving the problem of putting the pump, pipes, and valves where they could not be found, or *gluing* them to the wall in such a manner that to replace a bursted pipe or pack a valve or union would fill the unfortunate engineer with unspoken curse words.

Four years ago the writer had to pull down an opening in an outside wall so that he could take off the head of a large Knowles pump used for fire-protection. The millwright had placed it in a corner with the steam cylinder head, within one or two inches of the wall. To add to this inconvenience, all the pipes, valves, and unions on the water-end were under the floor, and the union on the steam pipe was put between the boilers and the globe-valve, thus making it impossible to pack the union or disconnect the pipe, if necessary, while steam was up.

I have seen pipes laid in narrow trenches along the walls half covered with mud and so rusty that they were nearly eaten through, and if one of them burst it would take a gang of men a long time to dig them up from their rusty grave.

I think it bad engineering to put up pumps in this manner, for instead it should be placed on a solid foundation, and in such a location as to be easily accessible. There should be space enough on all sides of it to work with ease, and of course the larger the pump the more room there should be. All valves and unions should be above the floor and far enough from the pump, wall, floor, and other pipes to permit wrenches, tongs, or hammers to be freely used. Water-pipes should never be buried under ground if it is possible to avoid it. If they must be put under ground, box them in so as to keep them dry, and in such a way that they can be examined, changed, or repaired without having to pull down the mill or move a mountain to get at them; and some means should always be provided to carry off all drippings of water or oil from pump or pipes.

Pipes lying partly in air and water soon rot, and must be replaced with new ones, thus adding to the running expense. Many engineers claim that water-pipes should be buried to keep

them from freezing. I think a better plan is to so arrange them that they can be boxed in and covered with sawdust or other dry covering. In putting up pipes, if an expansion-joint is used, great care should be used in placing it so that it can move either back or forward freely within its limits.

In pipe-fitting, if plumbago with oil is used on the threads, they will not rust and will come apart easy. Gaskets on which plumbago is used on one side only, become very durable, as they are not spoiled by being taken apart.

J. W. POWER.

ENGLISH EXPORTS AND THE TARIFF.

From Industries, London.

THE Board of Trade Returns for the month of November and the eleven months then ended can only be considered as very unsatisfactory, whether regarded from a general standpoint or in connection with the particular trades under review. The total value of the imports for the month amounted to £43,861,389, and for the eleven months to £392,429,299, being an increase of £6,709,116 and £10,973,052 respectively as compared with the corresponding periods of 1890. The total value of the exports for the month amounted to £18,790,949, and for the eleven months to £227,432,458, being a decrease of £2,234,604 and £14,725,772 respectively as compared with the corresponding periods of 1890. The total quantity of iron and steel exported for the month was 221,315 tons in quantity, valued at £1,802,447, and for the eleven months 3,018,026 tons in quality, valued at £25,007,291, being a decrease of 78,162 tons in quantity, and £717,071 in value, and 719,994 tons in quantity and £4,305,923 in value respectively, as compared with the corresponding periods of 1890. The decline in pig and puddled iron for the month amounted to 15 per cent. in value, in bar and angle iron to 24 per cent., in railroad iron to nearly 63 per cent., and in hoops and sheets to 22 per cent. We append the tabular statement, the figures of which would indicate a steady decline in the export demand for iron and steel, which may well give rise to serious apprehensions as to the condition of those industries. The falling off in the export coal trade is also a noticeable feature, more particularly having regard to the disquietude amongst the Continental colliers, which might have been expected to have given an impetus to this branch.

	Month of November.		Eleven Months.	
	1891.	1890.	1891.	1890.
Pig and puddled ...	190,857	224,308	2,059,108	3,335,354
Bar, angle, etc.....	113,485	148,917	1,347,889	1,482,240
Railroad.....	144,836	382,325	3,647,211	5,651,511
Cast and wrought ..	336,246	469,707	4,405,549	5,525,324
Hoops, sheets, etc	301,433	385,977	3,282,290	3,515,955
Unwrought steel.....	145,490	158,569	1,561,943	1,758,493
Unwrought copper.....	163,914	243,360	1,843,074	2,371,203
Coal.....	1,400,329	1,546,016	17,473,870	17,484,759

Turning to the home markets we find an equally unsatisfactory condition of things to exist. Although makers who took advantage of the temporary demand which occurred in September last have sufficient orders to keep their works fully employed up to the end of the year, there is a lack of fresh business which augurs badly for the opening months of the new year, and prices show signs of falling. As a matter of fact, some manufacturers are in a worse position now than they were three years ago, when prices were at their lowest level. Through the enhanced cost of production of the raw material, owing to the high rate of colliers' wages, there is probably less profit now on pig iron at, say, 42s. 6d. per ton, or bar iron at, say, £6 5s. per ton, than there was on pig iron at 33s. and bar iron at £4 15s., and we have no doubt that the published balance-sheets of public companies connected with these industries will afford good proof that such is the case.

THE REQUIREMENTS OF A STREET RAILWAY TRACK.

By Robert Grimshaw, M.E.

MANY persons design and still more lay down street railway rails and tracks without giving much, if any, consideration to the requirements which must be met. They have a general idea that a track should have two rails and that they should have a certain gage, but beyond that there is little considered. It may be worth while to take up, point by point, the desirable qualities that a street railway track should possess, and such consideration may lead to better track-designing and better track-laying.

There is, perhaps, no one particular requirement which is of more importance than any one other. In that respect a track is like a man: he must have a head and he must have a heart and a stomach, etc. He may get along without an arm or so, or live on one lung for a good while; but there is no one organ or member that is of more importance or interest to him than any one other. So with the track we had better take up the desirable qualities one by one, without necessarily implying that the one first considered is the one of pre-eminent importance.

You may say that vertical stiffness is a desideratum, both in each rail and in the track as a body; that is, it must be built to stand up under weight; not only the weight of the cars, but the several weights which may be imposed upon it. Vertical stiffness in the rail as a single thing irrespective of the track as a body is got by width and by depth of rail,—by depth much more than by width,—for a bar 6 inches wide and 2 inches deep, that is laid flatwise, will be only ⅓ as strong against vertical stress as the same bar laid edgewise; and a 2 x 8 will be four times as strong to bear weight, if laid edgewise, than if laid flatwise. Of course this applies only to rectangular sections, but the principle is the same: the strength of any part of a rail is directly as its width, and directly as the square of its distance from the neutral axis.

We find many rails which have too much strength in their heads and not enough below; that is, they are over-strong to resist compression, which is the stress to which they are submitted in their upper parts, and too weak to stand tension, which is the stress that they get in their lower parts. As a rail or beam is only as strong as its weakest part, it will be seen that there is no use, as far as weight-bearing is concerned, in putting extra metal in a part that is already comparatively too strong for another part. There may be some extra metal necessary to stand wear, but in many cases that is overdone, or the metal is put where the principal wear does not come. We may make memorandum No. 1, that a rail which is deep vertically is stronger, other things being considered, than one of the same weight that is shallow.

There is a certain amount of stress upon a rail, tending to bend it sidewise. It is not in street railway rails very great, except perhaps upon curves, but it is there; and it is well to have some lateral stiffness to resist it. This lateral stiffness is, with a bar of rectangular section, directly as the vertical depth and directly as the square of the width. Probably all the rails that are made and laid are too strong this way for the requirements.

Ability of the track as a whole to resist weight is given partly by the depth and width of the rail itself, and partly by the stringers, ties, or chairs. With stringers as with rails, the greater the width and the greater the depth the greater the vertical stiffness; but the stiffness is, as with rails, directly as the width, but directly as the square of the depth; so that it is better to have a 4 x 8 set edgewise than flatwise.

The track as a body is kept from sinking into the earth by the area of the bottoms of the stringers, chairs, or ties, and the resistance to sinking is directly as their combined areas; that is, the more ties, stringers, or chairs of a given size, or the greater their area for a

given number, the stiffer the track as a whole.

Additional resistance to lateral displacement is given by the sides of the stringers or chairs, and by the ends of the ties; and here the greater the area the less the sidewise giving, caused by the sling of the vehicles. Where the two rails or sides of the track are tied together, the inner rail on the curve tends to aid the outer one to keep its place, and of course the greater the number of ties or tie-bars, the more the inside track helps the inside one on a curve.

Endwise creeping of the track as a body is resisted by the sides of the ties, the front and back of the chairs, and the friction of the bottoms of the stringers upon the soil.

The joints are the weak places in almost every system of street railways. There are few tracks on which you cannot tell which is the up line and which is the down, by seeing which end of the rail is frayed or broomed out. It is always the end toward which the cars move that gets the wear, the reason being that the advancing car depresses the forward end of the rail on which it rests, and leaves a jog or step where it strikes the next rail, and the rail gets frayed and wears at this jog.

With fish-plates or similar joints the same rule applies as with the rails and stringers themselves. Strength to resist weight is given by vertical depth more than by width; that is, although a fish-plate an inch thick has twice the strength of one ½ an inch thick, one 4 inches deep would be 16-9 as strong as one of the same thickness only 3 inches deep. Other things being alike also, the longer the fish-plate or splice the stiffer the joint, because the rail has less leverage to break or bend the plate and to shear off the rivets or wear the rivet-holes. Up to a certain limit there is an advantage in length of splice-bars, but unless they are properly fastened, there is no advantage in extra length.

Other things being equal, a perfectly rigid track will last longer than an elastic one, and the rolling-stock will keep in better shape also, for every time that a car goes over a loose fish-plate or over a rail that is bent or sunken down, the joints of the car are racked, and in time the mortises get enlarged, the tenons weak, and the whole structure enfeebled.

CASTING STEEL.

Mr. P. Mahler, in an article on casting steel which was recently printed in *Le Genie Civil*, says, "For casting, steel should be fluid, homogeneous, free from blowholes and prejudicial impurities, especially from the oxides of iron. These qualities belong to a good steel, but unless especial care is taken to secure them in producing steel castings, a complete failure will be the result. Fluidity and homogeneity can be obtained by a sufficiently high temperature in the furnace, provided that manganese is added to the charge. This body forms with iron an alloy which spreads itself uniformly through the whole charge. Silicon is less satisfactory from this point of view, as the alloy it forms remains localized. As the oxidation of the bath will give a brittle and useless metal, this is prevented by adding to the charge a sufficient quantity of agents having a greater affinity for oxygen than iron, by means of which the oxides of this metal are reduced to the metallic state, or to the protoxide which passes into the slag. The substances employed are manganese and silicon, the former being most used, as silicon gives a weak metal. The formation of blowholes is also prevented by the presence of manganese in the bath throughout the process of the fusion, and by adding a quantily of silicon at the end of the operation the last traces of such blowholes are caused to disappear. In the present state of metallurgy it is unadvisable to try and expel sulphur and phosphorus from the metal while preparing it for casting, as such purification takes time, while to secure a metal free from blowholes the fusion should be made as rapid as possible. Hence only selected material, such as the cross ends of Bessemer rails, cast-

iron, etc., should be used for steel castings. Up to the present the acid process alone has given uniformly successful steel castings, as the basic hearth favors the oxidation of the molten metal. In melting the metal the composition of the charge should be designed to give as rapid fusion as possible. From the outset the furnace should be pushed, so that the temperature is very high at the end of the operation. When this is done but little oxidation of the metal will occur even before the final recarburation. The following composition for the charge has given good results :

	Per cent.	
Pig iron	16	melting charged.
Eighteen per cent spiegel	1.8	
Scrap (rail ends)	80	
Forty-five per cent ferro-manganese	1.2	addition to both.
Silicon spiegel with 10 per cent. of silicon	1	
Total	100	

The pig iron contained 3.5 per cent. of carbon, 2 per cent. silicon, and 1.5 per cent of manganese ; seven tons were melted and poured in seven hours. The metal finally obtained in the castings has usually from 0.2 to 0.5 per cent. of carbon, from 1.18 to 0.5 per cent. of silicon, and 0.320 to 1 per cent. of manganese. The following table gives limits, of which a great percentage of the constituent named is dangerous :

	Per cent.
Manganese	1.2
Silicon	0.60
Sulphur	0.08
Phosphorus	0.09

The resulting metal has a strength ranging from 28½ to 43 tons per square inch, with an elongation of 12 to 25 per cent. In pouring, one ladle only should be used. The metal solidifies rapidly, and the contraction (0.216 inches per foot) is large and irregular. The quantity required for a casting is larger than with cast-iron. Thus, for a heavy gear-wheel weighing 2.6 tons a charge of 3 tons of cast-iron would be sufficient, but with steel 3.8 tons of metal would be required. The sand abutting the cast must be of specially good quality and thoroughly dried, or there will be considerable disengagement of gas. When set in the mold the contraction goes on rapidly, and the sand must be removed where necessary to allow this to proceed without setting up internal strains.

Reflections and Observations.

THE reports in the daily press regarding boiler explosions or any technical matter furnish very amusing if not interesting reading at times. A short time ago I read of a fire which destroyed a pork-packing establishment, in which the report stated that the loss would prove very great, as a large refrigerating and ice plant costing one thousand dollars and a 5000 horse-power engine costing as much more were completely destroyed, and as everything in the establishment was of equally an expensive character, the loss will probably reach a high figure. To the ordinary reader there may be nothing strange about a 5000 horse-power engine, but the item reminded me of a story I once heard about a darky whose aunt had recently left him a small legacy. Meeting his employer soon after the news had been received, he told him of his good fortune.

"How much money did she leave you?" he was asked.

"Well, I dunno, boss, I didn't heared exactly yet, but it's either five million dollars or five hundred dollars, I dunno which, but it's a pow'ful big sum, anyhow."

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IT is not the daily press alone that prints such inaccurate news. The technical press, at times looking for news to print or upon which to comment, swallows these supposed facts, bait, hook, and line. I recall some of my early

newspaper work, and can assure you I speak from actual experience. About fifteen years ago I was connected with a daily paper in a small city not far from New York, and in my hunt for "news" a rumor of the basest kind would be pounced upon as a hungry man would attack a succulent and juicy steak. One evening I arrived back at the office without a story of any kind. The editor was disgusted, and told me he thought it strange that I couldn't hear of some calamity.

I informed him that the only thing I had heard was of a boiler explosion, which had killed the proprietor and engineer, but I added that I had investigated and discovered that it was not a fact.

"What!" said the editor, "you come back here and tell me there is no news when such a rumor is going round? You are no newspaper man; you should be a preacher."

"But," I protested, "the boiler didn't explode. It was only a small can of benzine."

"Never mind what exploded," he replied; "write me a column—mind you, a whole column—about the affair, and be sure to say that the list of the dead and wounded could not be learned. Say that the boiler was a poor old rattle-trap machine and should have been condemned long ago, and to-morrow you can use a column more denying the whole story, and say that it originated in the mind of some malicious person."

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I AM ashamed to confess that I did as I was told, and in the morning the story of the boiler explosion attracted a great deal of attention. I had forgotten all about the occurrence, when a a few days afterward I happened to glance at one of the engineering publications which had just arrived by mail. Lo, and behold! there was my report of the mysterious boiler explosion and almost a column editorial in which the proprietor was condemned in the strongest terms for employing a poor engineer and not having his boiler inspected.

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As engineers know to their sorrow, feed-water containing magnesium chloride should not be directly used, says an English technical journal. Treatment with caustic soda in the boiler itself is frequently resorted to, but the great difficulty lies in ascertaining the amount of caustic soda necessary, and in keeping only slight excess present. Usually samples are drawn off from time to time and tested, litmus being used as indicator, but a simpler method would seem to be the introduction of an indicator into the boiler. Most indicators become colorless on heating under pressure; Mr. A. Goldberg—*Chem. Zeit.*—proposes, however, sodium para-nitrophenolate, which does not possess this disadvantage. In taking an observation it is only necessary to blow off the water from the water-gage and to admit a fresh portion from the boiler. The indicator in the pure state is dear, but perfect purity is not essential. Continuous use of the indicator is not necessary, for when once the working quantity of caustic has been ascertained the indicator may be dispensed with for a while. With regard to the working of this indicator, so long as the water in the boiler is alkaline there is direct indication, but directly acidity prevails, reduction takes place to amidophenol, and direct indication ceases. The indicator is best prepared on the spot by dissolving para-nitrophenol in a dilute solution of caustic soda.

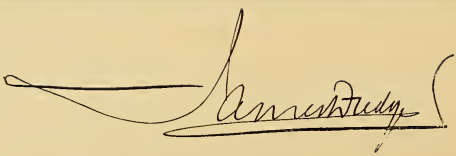
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SOMETIME during the summer I was walking across the great Brooklyn bridge when I observed two gentlemen examining with great interest one of the "joints" in the frame of the bridge which has been provided for expansion and contraction. They were apparently in a quandary as to the reason for the peculiar construction. After suggesting several reasons, one of them evidently solved the problem, for he said to his companion, "I know why they put that there."

"Yes?"

"Those engineers who built it thought they were so smart, but they couldn't guess within a dozen feet near the correct length of the bridge, so they made it big enough so it would slip in those sockets."





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AUTOMATIC SPRINKLERS.—I.

By C. J. H. Woodbury, Vice-President Boston Manufacturers' Mutual Fire Insurance Company.

THE smoking ruins of burned buildings portray a sacrifice to the annihilation of property, destroying the results of labor; and, as labor is life-work, the great fire-loss diminishes the resources of this country by amounts which might be as correctly estimated in lives of able-bodied men as in dollars. A fire-loss is a loss; all other losses resulting from human intervention are merely transfers of possessions.

Any act which reduces the fire-loss is as high a deed of philanthrophy as are the good works which increase health and prolong life.

The burning of a building differs in nowise from the burning of fuel for heat or power, in regard to its physical conditions; and the same material, which, as a part of a building, contributes to such destructive results in a conflagration, might in cheaper form have served a useful purpose as fuel. The floors of mills and manufacturing buildings are of sufficient calorific value as fuel to evaporate by their combustion a quantity of water equivalent to the depth of two to three feet upon such floors. It is not surprising that this great amount of fuel should have attracted attention as a source of energy which might in turn be used for the self-extinguishment of fires.

The ablest mechanicians of England and America have devised various forms of apparatus by which water should be liberated by the heat of a fire and ejected upon the burning material. The initial step for the operation of such apparatus consists in the action of the fire in causing the ignition of explosives, the burning of combustible cords, the fusion of cements or of solders, the softening of compounds of asphaltum, the generation of vapors from alcohol and ether, the expansion of wax compounds,

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or the bending of compound bars of brass and steel, all of which have been applied to numerous operative devices in various forms of automatic sprinklers.

In this department, as in all inventions of modern times, the records of patent offices give names and dates of inventions which were sufficiently prized by their progenitors to be deemed worthy of that protection forbidding all others to "make, vend, or use," as set



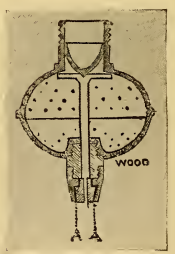


forth in letters patent, and in this manner preserving from oblivion the record of many devices severely let alone by unappreciative contemporaries.

Ambrose Godfrey, a celebrated chemist, patented November 12, 1723, an automatic fire-extinguishing apparatus which comprised a cask of fire-extinguishing solution which contained a pewter chamber of gunpowder connected to a system of fuses. This device reached to some prominence, as a pamphlet on the subject describes its operation in test buildings three stories in height at experiments made in the presence of high officials.

Bradley's *Weekly Messenger*, November 7, 1727, refers to its efficiency in stopping a fire in London. This device was probably introduced to a limited extent, but, like the London fire, it became forgotten, until, at the request of the son of the inventor, the Society of Arts made a test of the device in a three-story brick house containing a large amount of faggots and shavings. Royalty and nobility were present and the operation of the apparatus was declared to be successful in the contemporaneous account in the *Gentleman's Magazine*, May 19, 1761.

The next invention appears to be that of John Carey, who patented in 1806 an apparatus for the "extinguishment of fires in gentlemen's apartments and warehouses," which included a system of rose-sprinklers connected on pipes supplied by an elevated tank, but water was kept from the pipes, except at fire, by weighted valves kept closed by combustible cords. This device was probably of no practical value except in the production of unpleasant mishaps from the leakage consequent upon the natural stretch or weakening of the cord in course of time, unless perhaps the valves had been securely rusted in place.



SECTION OF HARRISON AUTOMATIC SPRINKLER.

Sir William Congreve, eminent as a general of ordnance, known to fame as the inventor of the Congreve rocket, a hydraulic engineer, and a member of Parliament for many years, gave the problem of automatic sprinklers serious attention for several years for the purpose of protecting British arsenal

buildings. In a carefully written patent, February 7, 1809, he claimed a system of rose-sprinklers with combustible cords leading to valves in a place of "outside security and arrangements for a further supply of water by water mains or by hose connection to fire engines." In a later patent, October 30, 1812, he abandoned burning cords and used a cement fusible at 110° "or less." In this patent he states the functions of an automatic sprinkler to be "an apparatus for extinguishing fires which shall be called into action by the fire itself at its first breaking out and which shall be brought to bear upon the precise part where the flames exist," a description which comprises all that could be said under the state of the art as it exists to-day.

Unfortunately the illustrations of the apparatus show that his mechanical skill did not equal his mental conception of the problem.

A period of forty years elapsed before there was another invention upon automatic sprinklers, and this was of so little value as a contribution to the art that with two others of later date it can be omitted, and fully warrant the statement that the next improvement in automatic sprinklers was not made for over half a century after Congreve, when, early in 1864, Major A. Stewart Harrison, of the First London Engineer Volunteers, made the invention which included the greatest advance made by any one inventor up to the present date.

The sprinkler consisted of a large rose-head containing numerous perforations countersunk on the outside. Water was shut out at the neck of the sprinkler by a cup-shaped rubber piston-valve resting on the disk at the top of a rod, which was in turn supported by the conical plug held in place at the bottom of the sprinkler by fusible solder (*A*, *A*).

The interior of the neck of the sprinkler was tinned to prevent adhesion of the rubber valve to brass, and the soldered joint was attached to the body of the sprinkler by a piece of wood which served to render the sprinkler more prompt in its operation. The arrangement of the valve, which moved without opening, was such that water was not admitted to the sprinkler until the soldered joint was entirely released, while the disk at the top of the rod, the projection on the interior of the sprinkler, and a sharp projecting ring around the lower part of the sprinkler were all arranged to prevent any leaking water from reaching the soldered joint. It is worthy of especial notice that the fusible solder was under compression and that it is not exposed to any stresses except the pressure of the water, and it was contemplated that the rubber valve should be renewed every two or three years.

The methods of installation, as proposed in a publication at the time of the invention, show that the arrangements included about everything now considered necessary for a system of automatic sprinklers. The sprinklers were to be placed from six to ten feet apart, according to the combustibility of the contents of the room, and hung pendant from pipes placed against the ceiling in the identical manner now used; the elevated cistern for supplying the sprinklers with a constant head of water, the check-valves in the supply-pipes, the limitation of the number of gate-valves to one or two, and the fire-alarm bell actuated by a circulation of water in the pipes whenever a sprinkler opened, are all conditions generally considered original in modern practice, while the Harrison automatic sprinkler anticipates nine United States patents.

The invention of this sprinkler is not a matter of patent-office record, as Major Harrison applied first for provisional protection, but as his efforts to interest others in the device did not result in success, he never took the further steps necessary for the issue of the letters patent. His numerous addresses and experimental fires were very fully reported with illustrations in several journals and books* at that date, and the record is fully established to the minutest details.

Harrison invented an original automatic sprinkler system which has not

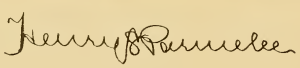
*See London *Times*, August 17, 1865; *City Press* (London), May 20, 1865; *English Mechanic*, August 19, 1865; *Pharmaceutical Journal*, June 1, 1865; also "Fires, Fire Engines, and Fire Brigades," by C. F. T. Young, London, 1866, pp. 48–49.

been equaled except by those made within a few years on the basis of later experience ; and at this time and point of view it is difficult to surmise what conditions stood in the way of its commercial success.

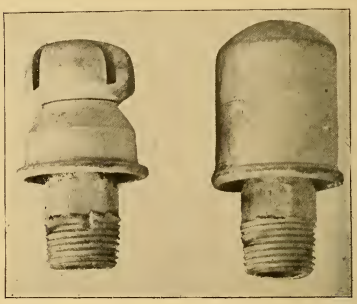
Outside of engineering work, Major Harrison has been a fertile inventor, having originated the stellar code of international marine signals, which is also the foundation of the railway signals in general use, and also the spade bayonet.

He is perhaps most widely known in the field of letters as a writer of fiction, travels, and a few poems.





The low fusible alloys used in automatic sprinklers were first made by Sir Isaac Newton when master of the mint (1699). He discovered that certain alloys possessed lower melting-points than any of their constituents,* the lowest alloy which he produced being one composed of bismuth 5 parts, lead 3 parts, and tin 2 parts, and melting at 212° Fahr.



PARMELEE AUTOMATIC SPRINKLER.

At a later day Professor Rose, of Dublin University, changed this alloy to bismuth 2 parts, lead 1 part, and tin 1 part, which melts at 200° Fahr.

The solder generally used for automatic sprinklers consists of bismuth 4 parts, lead 2, tin 1, cadmium 1, and is based on United States patent granted to Barnabas Wood, of Nashville, Tenn., March 20, 1860, and has a fusion-point of about 165° Fahr. There are about fifty of these solders, which are empirical in their composition, and do not form pure alloys.*

Professor Frederick Guthrie, F.R.S., investigated these solders, and in a paper read before the Physical Society (London), May 24, 1884, of which he was president, stated that he had made a true alloy with melting-point 159.8° Fahr. composed of

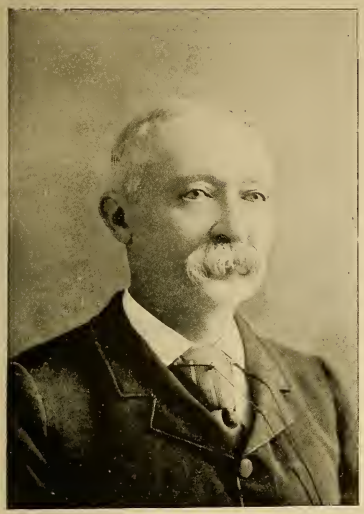
Bismuth	47.38
Lead	19.36
Cadmium	13.29
Tin	19.97
	100.00

* The melting-point of cadmium being 600° Fahr., lead 504°, bismuth 476°, tin 421°.

*Journal Franklin Institute, Philadelphia, lxi, page 125. Gill's "Technical Repository" (1828), vol. iii, page 364. Haswell's "Engineers' and Mechanics' Pocket-book." Gemlin's "Handbook of Chemistry" (London, 1846), vol. v, page 181. "American Journal of Science" (1860), vol. xxx, page 89.

Alloys of lower melting temperatures have been made by the admixture of gallium, but this rare metal is too expensive to receive any consideration for practical application.

An automatic sprinkler does not open at the melting temperature of the solder,



Chas Barnes

but at the critical point when the solder assumes a granular condition when passing from solid to liquid form.

Careful investigations made upon these solders do not reveal any change of melting-point due to the effect of time on the solder; and, as a practical fact, it is well known that the earliest installations of automatic sprinklers extinguish fires as efficiently as new sprinklers of the same type when there is not any changed condition except that which might be due to time on the solder, if such a change existed.

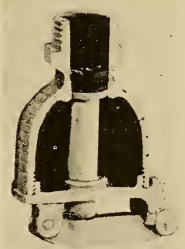
Whatever may have been the merits of earlier automatic sprinklers, the first commercial automatic sprinkler, manufactured and sold for actual practical service in the protection of property, was that invented by Henry S. Parmelee, of New Haven.

For many years after it was patented, August 11, 1874, it completely held the monopoly, notwithstanding that the state of the art was such that the fundamental principles in automatic sprinklers were public property, and any automatic sprinkler containing new mechanical features could have been patented.

The Parmelee sprinkler consists of a small reaction turbine covered with a brass cap soldered at the lower part of the rim, simple in construction, secure against leakage, and so efficient in its operation at hundreds of fires as to open a new era in fire protection of manufacturing establishments and modify methods of insurance.

Upward of 200,000 of these sprinklers were placed in factories before the manufacture of these sprinklers yielded to those of another type, which in turn was displaced by further improvements.

Charles Barnes, of Cincinnati, is among the earlier inventors, producing an automatic sprinkler patented February 18, 1879, being of the class known



BARNES AUTOMATIC SPRINKLER.

as the sensitive type, with the soldered joint placed at the extreme end of the sprinkler far away from the cooling influence of the water. The stem to the valve at the neck of the sprinkler is supported by a lever secured at the extreme end by a latch held fast by fusible solder.

Mr. Barnes has made several different

automatic sprinklers and other devices subsidiary to sprinkler systems, all of which show a full appreciation of the numerous difficulties which have stood in the way of the construction of automatic sprinklers.

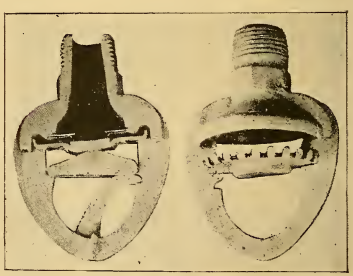




No reference to automatic sprinklers can be made without allusion to the work of Frederick Grinnell, of Providence, who has been more fully identified with the invention, exploitation, and development of automatic sprinklers than any other person.

From the first, he was the manufacturer of the Parmelee sprinkler until the summer of 1881, when he produced the first of the sprinklers bearing his name. The water-joint sprinklers in which the device was sealed by means of a cap on the outside, or a plug within, secured by fusible solder, were proof against leakage, but were relatively slow in action, because the seal could not be melted until a large body of metal and the water which it contained was raised to 160° by the fire. On the other hand, the sensitive or valve sprinklers were liable both to leakage and to adhesion of the valves to such a degree as to unfit them for practical use, and the writer does not know of a single instance of the sale and introduction of any valve automatic sprinkler previous to the one invented by Frederick Grinnell.

In all earlier sprinklers the distribution of the water was effected by forcing it through small holes or perforations in the body of the sprinkler, producing the subdivision of the water by the interposition of any obstruction which would confine the water except at these orifices. In the Grinnell sprinkler a stream of water issuing from an orifice half an inch in diameter impinged upon a splash-plate, and was deflected laterally and upward as desired according to the contour of the splash-plate. As a hydraulic principle this is of higher efficiency than the former method owing to the smaller amount of frictional loss, and such a sprinkler will not become clogged by any foreign matter in the water able to pass through an orifice half an inch in diameter. Since the invention of the Grinnell sprinkler all automatic sprinklers are made with a large opening and a splash-plate, and the use of rose-heads has been abandoned for such purposes.

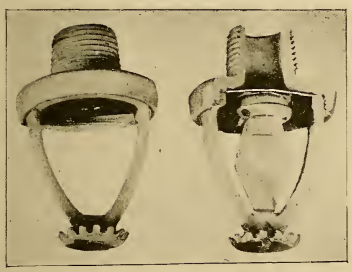


GRINNELL LEVER AUTOMATIC SPRINKLER.

The ring forming the valve-seat at the opening of the sprinkler is placed in the middle of a flexible diaphragm, and presses against the valve of soft metal in the middle of a splash-plate with a

serrated edge turned upward, similar to a crown-gear.

This valve is kept closed by a pair of compound levers, of which the second one is secured at the extreme end by fusible solder to the yoke of the sprinkler, and the solder-joint reinforced by a small piece of wire in the form of the letter L, which makes a compound joint lying in three planes and of great strength in resistance to the water-pressure on the sprinkler. A marked peculiarity of this sprinkler is the arrangement of the valve in the middle of a flexible diaphragm, which is so much larger than the valve that any increase of water-pressure exerts a greater force on the diaphragm than on the exposed surface of the valve; and therefore an increase of water-pressure tends to render the sprinkler less liable to leakage as long as the valve is held in place by the rigid supports, but when these are removed by the fusion of the soldered joint, the same water-pressure forces the valve open.



GRINNELL NEW AUTOMATIC SPRINKLER.

The Grinnell automatic sprinkler has in itself been fully sufficient to establish the utility of automatic sprinkler service, having operated successfully at over 1200 fires, the greater portion of which originated in highly combustible materials in process of manufacture, as cotton, jute, wool, and rags. A few years ago a supposed improvement was made in this sprinkler, by substituting block-tin for lead in the valve-seat, and diminishing the width of the ring on the valve, on the supposition that the harder metal would resist the greater intensity of pressure from the narrow seat-ring. After about four years it was found in the course of laboratory experiments on sprinklers which had been subjected to a heavy pressure that the cold flow of the tin had in some instances permitted the narrow seat-ring to imbed itself into the tin and adhere quite firmly to it. These sprinklers have still performed good service in many actual fires without failure, and while there is not any reason to justify a statement that they have become inoperative, yet they are impaired, and in course of time this defect will naturally increase until the sprinklers would not open unless the block-tin valve-seat was softened by the heat from a fire. The only prudent course has been to change the relatively few sprinklers of this type, and substitute others of an improved construction. When this defect was found to exist, Babbitt metal was substituted for block-tin, and proved to be a great improvement, serving its purpose fully, although the glass-valve is considered to be a further improvement.

The exposed levers of this sprinkler are liable to corrode under any conditions which will act upon rolled brass.

Grinnell has produced a new sprinkler which avoids the defects which time and experience revealed in his former device. Retaining the principle of an elastic diaphragm, the new valve is made of a hemispherical piece of glass which is made to fit tightly by means of a thin ring of Babbitt metal around the orifice in the middle of the spring-plate. This valve is held in place by a strut made of several pieces of metal soldered together and resting against a yoke which also holds the deflector. Every portion of this strut which moves when the sprinkler operates is covered with solder, and the sprinkler is proof in this respect against being disabled by corrosion.

(To be continued.)

THE ANIMAL AS A MOTOR-MACHINE.

By Professor R. H. Thurston; Director Sibley College, Cornell University.

HIRN was probably the first and the greatest of those who have sought to measure up the energies of living creatures, and to follow the transformations which occur in the processes of vital organization and animal exertion.*

The origin of heat in the bodies of living animals has been a matter awakening the greatest interest and curiosity from the earliest times. The ancients thought heat and light a part of the vital power, due to the creative act and without immediate source in the processes of vital existence. They thought the act of breathing a necessary process of cooling and removal of excess of this spontaneously generated heat, due to the fact of life simply. Since the establishment of the principles of energy in modern times, however, the philosopher has only concerned himself as to the method of production of this heat, recognizing the fact that it must have its origin, as must all the exhibitions and expenditures of energy that accompany it in the living being, from the potential and latent energies of combustible substances subjected to the processes of digestion and assimilation in the body. The scientific man of later times sees in the vital processes a transformation of energies originating in a slow combustion at low temperature, with changes of form of the resulting energies which, though none the less certain phases of the chain of vital phenomena which he studies, are not all fully understood, or as yet all detected and rendered evident by research. The chemical compositions of these combustibles are known; the quantities of energy which may be obtained by their perfect combustion to carbonic acid and water are well ascertained, and it only remains to determine the exact nature of the processes by which it is possible to effect the combustion at the temperature of the animal system, and to utilize by transformation the resulting power through those intermediate forms of energy-change which remain as yet undiscovered, and, in that sense, mysterious. We do not yet know how to produce combustion at a temperature of 98° Fahr., that at which combustion certainly does occur in the human system; or at the still lower temperatures at which such chemical changes go on in the bodies of cold-blooded creatures; nor do we know how to secure transformation of heat into mechanical and other forms of energy without sensible change of temperature and with high efficiency. In all our uses of heat-engines the wastes are a much greater proportion of the available energy than in any animal system, except where, as in some cases of application of the heat-energy of steam, for example, the wastes of the engine are, as in the human body, utilized for heating purposes.

In 1856–57 Hirn experimented with men engaged in regular work and at rest, and found that when at rest they produced a quantity of heat almost exactly, if not precisely, proportional to the amount of oxidation, as measured by the quantity of oxygen absorbed by them and exhaled in carbonic acid.

This was not precisely the case when they were at work. The principle of equivalence of energies then takes effect, and the measure of all the energy produced by oxidation is found in the sum of the heat discharged from the system and that energy of work which stands for the parts converted into dynamic forms.*

Hirn found that the quantity of heat generated by the human body at rest, whether that of men of middle age, or youth of either sex approaching maturity, was substantially the same under the same circumstances: about 5 calories

* La Thermodynamique et l'Étude du Travail chez les Êtres vivants. G. A. Hirn, Paris. *Bureaux des Revues*, 1887.

* L'Équivalent mécanique de la Chaleur. G. A. Hirn, 1858.

per gramme of oxygen inspired and exhaled as a minimum, 5.2 as a maximum, and usually the latter figure. The differences may be ascribed to variations in observations, rather than to real differences of fact. Precisely the same quantities of air were measured as exhaled as were measured as inhaled, in all cases. A singular and significant fact was, however, discoverable in the results, as reported by Hirn: The quantity of heat produced per unit of oxygen absorbed and converted into compounds exceeds by a third the amount computed upon the basis of the experiments of Favre and Silbermann. This result would seem to indicate other sources of heat than combustion with oxygen. It may be due to oxygen absorbed and exhaled through the skin; to the conversion of stored energies as yet undetected in the system; or to the combination of other elements, as carbon and hydrogen, through processes resulting in the production of heat.* It is to the latter cause that Hirn would ascribe this excess of exhaled energy. This subject remains still to be investigated.

The same individuals being set at hard work in a treadmill constructed for the purpose, in such manner as give the figures for a normal condition of labor, unforced but steady, and at a maximum for a day's work, gave out but about one-half as much heat per unit of air breathed and of oxygen consumed, showing clearly the transformation of heat into work. The efficiencies of the human system, considered as a heat motor or engine, ranged, according to the condition and temperament of the subject of the test, from 17 per cent. to 25 per cent. when raising the load or themselves ascending, and rose to 30 and 40 per cent. in descent. A lymphatic youth of 18 gave the lowest figures; a strong man of 47 the highest. These results all exceed those obtainable as yet from the most economical forms of existing gas- or steam-engine, in which 16 per cent. may be taken as about the contemporary limit of their efficiency as heat-engines.

To have secure this efficiency in the human body as heat-engine subjected to the accepted laws of thermodynamics would demand a temperature within its working parts not far from 140 centigrade (284° Fahr.), or far above the boiling point of water. This fact is crucial as a proof that the transformations of energy in the animal system are not, in the accepted sense, thermodynamic. They must involve as yet unknown processes and methods, and must be free from the control of thermodynamic principles, as we are accustomed to denominate them. The "second law of thermodynamics" is here evaded.

In those cases in which work was done, the production of heat was as much less than that anticipated, as computed from the engineers' and the physicists' experiments, as, in the case of rest, that figure was exceeded, falling in the latter case to from 2.5 calories to 3.5 per gramme, varying with the individual and his familiarity with the work, and consequent efficiency as a machine.

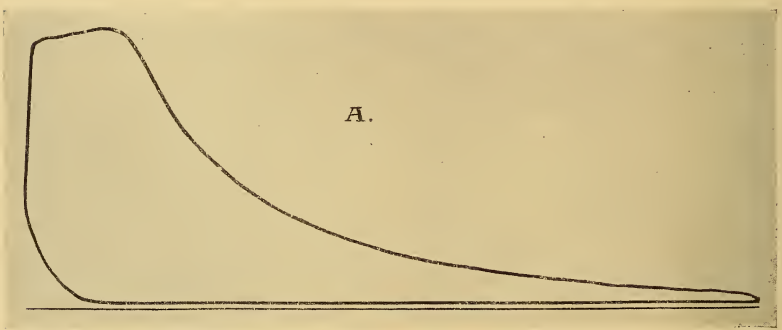
Thus the work of the great investigator shows, that while the animal system is unquestionably a machine producing and utilizing energy by transformation, it possesses some peculiarities and conceals some secrets that science has still to discover through exact methods of research. It further has become evident that these methods of production and utilization of energy include some which are very different from those familiar to us, as exhibited in our inanimate heat-engines, and which, once discovered and given application, should that prove practicable in artificial machines of this class, will probably prove enormously advantageous in the saving of costly energies now so largely wasted. Could we discover and apply these methods in displacing our heat-engines it would give us direct transformations of energy into work at low temperatures, with little or no wastes, and thus enormously extend the period of human life on this globe, as well as its productiveness. It will be an interesting question for the electrician and the engineer to settle: whether these as yet mysterious processes are not electrodynamic or related phenomena.

*See Sarason: *Revue Scientifique*, 1887, page 306 *et seq.*

ADJUSTING CORLISS VALVES.

By Thomas Pray, Jr.

ONE of the most difficult problems which confront the engineer in charge of one or more engines is the proper adjustment of the valves, and as an engineer, as a rule, possesses but one indicator, he is rarely successful in making the proper changes which the builders themselves often make necessary. The diagrams on this and the following pages were taken from a pair of Corliss engines coupled on the same shaft, four being obtained as the engines were found when the writer was called upon to make such changes as were necessary to allow the engines to run regularly. This had not been possible since they had been put in position, although the valves were set as they had been left by the builders, having been set up by one of their employees, who of course should, for the interests of the makers, if for no other reason, have done the work properly.



FROM RIGHT-HAND ENGINE, CRANK END, H.P. 154.40 BEFORE ADJUSTMENT.

The trouble was largely caused by the fact that both of the engines were not set so as to develop the same amount of power, and an idea of the condition of things may be gleaned from the following facts :

The engine was making 64.7 revolutions per minute, jumping very clearly on each live center, the shaft out of round on one side more than one-eighth of an inch, one cross-head loose on the taper, some of the brasses were loose, and the left-hand crank-pin had a quarter-inch stream of water running on it, but remained hot nevertheless. The reason for all this trouble was an element of extreme uncertainty. It had been supposed that the difficulties were caused by "dust coming in at the windows," "grit in the oil," "pull of widest belt on that side," and "spring of the shaft," or from "its being out of round." As there is usually to be found on examination a good reason for any observed result, so, in this case, the cause was found.

If the reader will examine and compute the first four diagrams A, B, C, and D, it will be seen that the initial H.P. shown was as follows :

A, 154.40
B, 221.90
C, 171.98
D, 124.57

Now, as the engine was running at 64.7 revolutions per minute, if we multiply the foot-pound of thrust at each revolution made by the exertion, 64.7

times the mean pressure on the piston or the whole stroke, the total exertion per minute will be as follows :

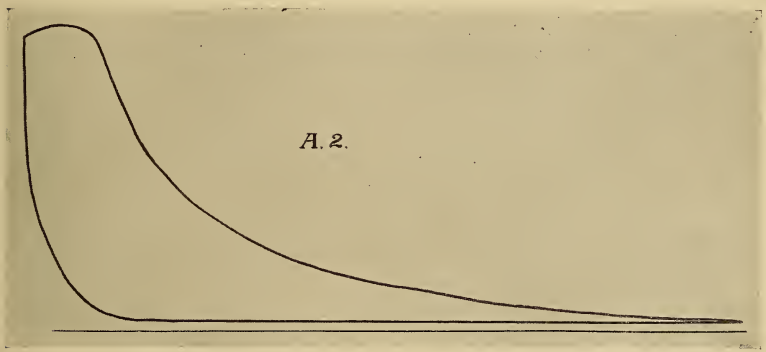
B, 7,322,700 foot-pounds.
C, 5,675,330 "
A, 5,095,000 "
D, 4,110,810 "

As the diagrams in their order represent the sequence of the strokes made, the varying amounts of power exerted by the different ends of the two cylinders, and of the foot-pounds exerted per minute, it will be seen in the completion of the cycle of motion that D is the last of the movements and B the first, and the difference between them amounts to only 3,211,990 foot-pounds! This exat the rate of 25 tons,—nearly 970.5 times an hour, or 9705 times a day. If, then, the "hammer" action is considered on the parts of this engine, the following difference is found per stroke :

As between B, D, 49,643 pounds.
" " B, C, 25,460 "
" " B, A, 34,428 "
" " C, D, 24,183 "

or as between each and every change of force exerted on the crank-pins there was a hammer which amounted to :

1 × 24.0 tons.
2 × 12.5 "
3 × 17.5 "
4 × 12.0 "



FROM RIGHT-HAND ENGINE, CRANK END, H.P. 127.30 AFTER ADJUSTMENT.

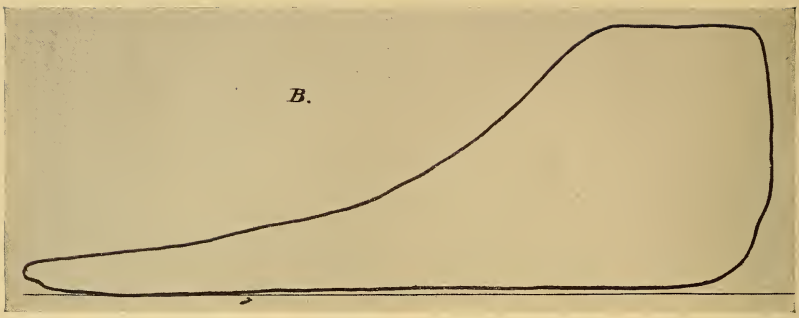
traordinary amount of difference was exerted 16 or 17 times in each minute of time the engine was running for each day, or 9705 times in ten hours. Given per each stroke, the pressure was :

B, 113,179 foot-pounds.
C, 87,719 "
A, 78,751 "
D, 63,536 "

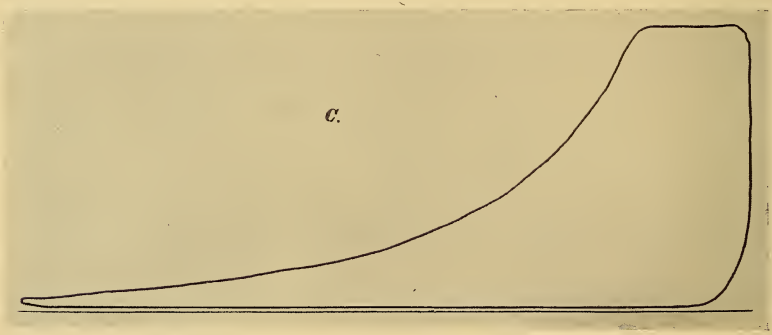
As is stated, the actual energy imparted at each stroke by B was 113,179 foot-pounds, while to D it is only 63,536 foot-pounds. Thus a violent blow to the cross-heads, connecting-rods, and crank-pin shaft was transmitted to the corresponding crank-pin, connecting-rods, and cross-head of the other side,

In corroboration of the facts it may be added that as shown by the diagram B the thrust on the taper of piston-connection with the cross-head was gradually opening the cross-head to such an extent that it was afterward condemned. On the other side the crank-pin was badly cut.

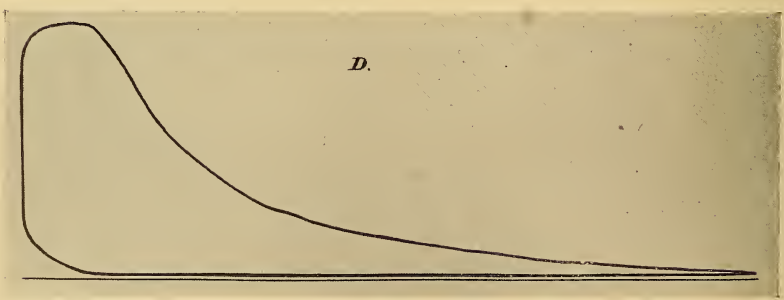
In order to start the mill at once the adjustments were made as speedily as possible; eccentrics were first set forward on the shaft about one inch, and the separate valves then put into position without any especial effort to get them into the exact place. The engine was then left to run a few days and to settle into its new bearings before final adjustment. On figuring the next set



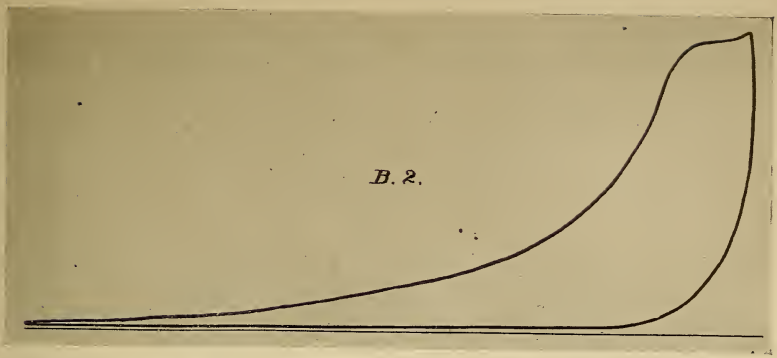
FROM RIGHT-HAND ENGINE, BACK END, H.P. 221.90 BEFORE ADJUSTMENT.



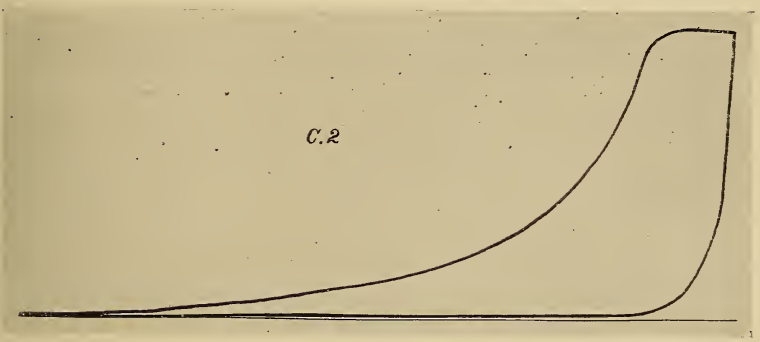
FROM LEFT-HAND ENGINE, CRANK END, H.P. 171.98 BEFORE ADJUSTMENT.



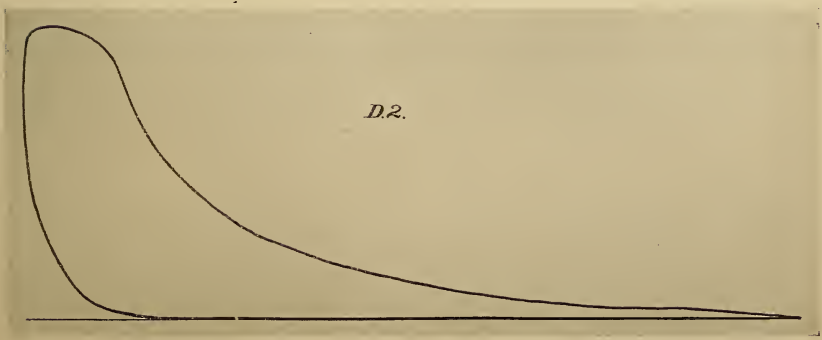
FROM LEFT-HAND ENGINE, BACK END, H.P. 124.57 BEFORE ADJUSTMENT.



FROM RIGHT-HAND ENGINE, BACK END, H.P. 127.80 AFTER ADJUSTMENT.



FROM LEFT-HAND ENGINE, CRANK END, H.P. 126.80 AFTER ADJUSTMENT.



FROM LEFT-HAND ENGINE, BACK END, H.P. 125.90 AFTER ADJUSTMENT.

of diagrams taken after the changes had been made, the greatest difference in them was found to be between 15 and 16 I.H.P. instead of 97.33 I.H.P., as at the beginning. The final adjustment was delayed thirty days, and upon the second test it was found that the water on the crank-pin had been unnecessary and that no further trouble had occurred. All the brasses had been out and set up, while the speed had increased from 64.7 to 66.4. In fact, the engine was running easily and smoothly.

Upon arranging to make final adjustments on the same engine, only slight changes were needed, except with the "cut-off" and "safety." Before making these, four sets of diagrams were taken and closely figured, but the greatest difference was 17 H.P. less than one of the four, with its three companions, and an average of over 50 H.P. above the total amount shown by the first four diagrams, A, B, C, and D. The steam-gage at the time of this adjustment registered 100 pounds, while the pressure in the various cylinders varied from 87 to 92 pounds, or a loss of from 8 to 13 pounds initial pressure. In this instance the valves did not open properly, and the real capacity of the port was not shown, as the throttling action of a delayed opening makes it insufficient on account of the increased piston speed at the instant of starting from the dead center.

Referring to the diagrams A 2, B 2, C 2, D 2, taken from the same engine on full adjustment, with steam at 97 pounds, the initial pressure will be found to be almost identical with the gage-pressure. It will be seen that the admission is unobstructed in three valves, the fourth being a trifle loose from a broken blade which was not closely adjusted when repaired. Terminal pressures are all within one pound of each other, and the I.H.P. shows

A 2 to be 127.30,
B 2 " 127.80,
C 2 " 126.80,
D 2 " 125.90,

or less than 2 H.P. from the highest to the lowest, and less than a single H.P. on either side between the ends of each cylinder, showing a close approach to balancing.

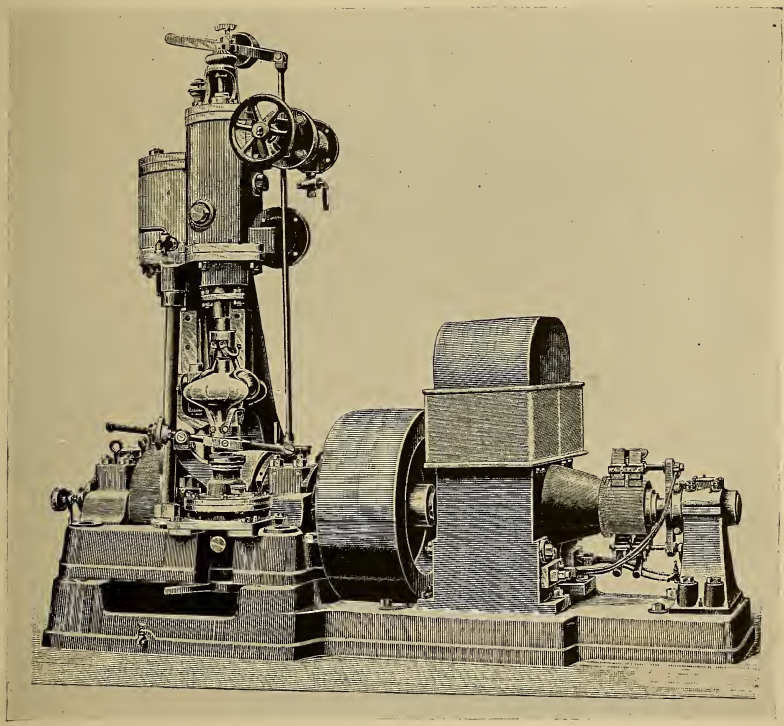
The point of making an engine run easily balanced is not judicially considered by many who, it is supposed, are closely identified with the use of steam-power, and there seems to be on the whole a total lack of any standard. Now, as a matter of fact, the engineer in charge of these engines was a practical man, and as far as he was able (with one indicator) he had endeavored to discover the cause of the trouble. But with one instrument this could not be done. All of the first four of the diagrams shown in this article (A, B, C, D) were taken at the same instant and each of the second four in the same way by the writer and his assistant, and there is no doubt that it is a useless waste of time to attempt to obtain necessary data from a pair of engines in any other way.

AN INTERESTING ELECTRIC PLANT.

PERHAPS the most striking of all the exhibits at the Frankfort Exhibition was that of the Actien Gesellschaft Helios, of Ehrenfeld, near Cologne. This firm is practically the same as Ganz & Co., of Budapest. Their chief exhibit was a large central-station engine and dynamo, which is illustrated on the two following pages. The engine was built by Messrs. Paucksch, of Landsberg, and develops 600 horse power. As will be seen, the fly-wheel is replaced by a rotating field magnet with forty-eight poles laminated cores, the winding being coupled to give 2000 volts and 200 ampères. The armature is built of T-shaped stampings, insulated with paper, as is usual with

Ganz machines. This one did not run silently. The noise in such dynamos appears to be largely due to magnetization and demagnetization of the iron. In machines in which the induction changes merely in direction—that is to say, in those with smooth armatures—there is no hum until the load is put on.

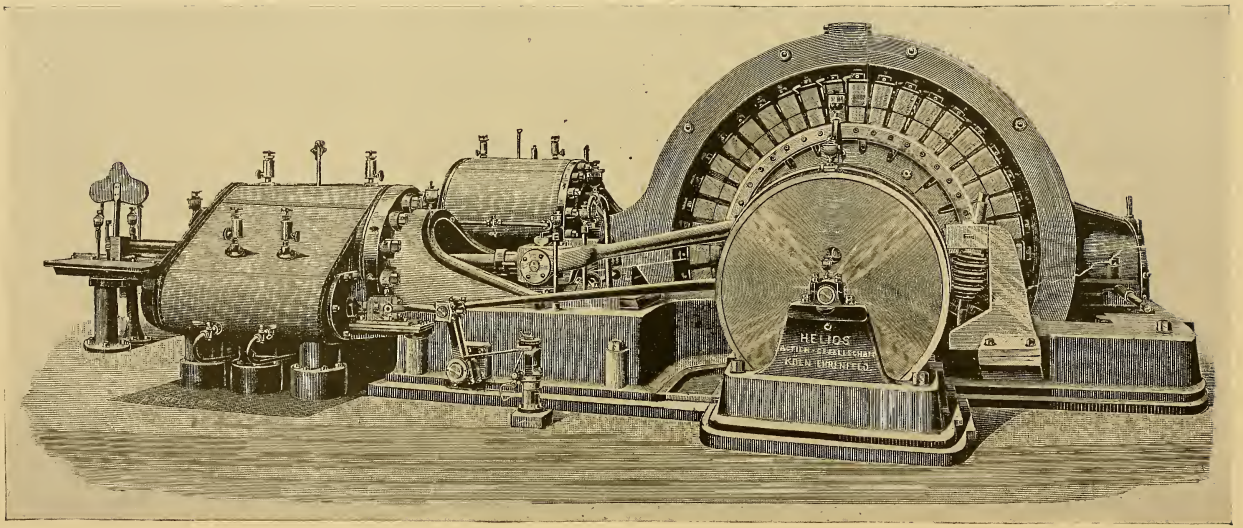
The engine is of the compound type, with injection condenser. The cylinders are 23 inches and 40 inches in diameter, the stroke being 33 inches. The air-crank is worked by a bell-crank from the back end of the low-pressure piston-rod and is placed underground. The high-pressure cylinder and receiver



SMALL PLANT USED FOR EXCITING LARGE PLANT ILLUSTRATED ON THE FOLLOWING PAGE.

In the Ganz machine even the field induction must vary considerably during a period. The dynamo is driven at 125 revolutions per minute, so that the frequency is very low; namely, 50. The field magnet is 10 feet in diameter and weighs 16 tons. The engine and dynamo weigh 85 tons altogether.

are jacketed with live steam, the entire plant being different from any American practice. On this page is shown a small plant built for the same firm. It was used for exciting the large plant which is illustrated on the following page. The illustrations used were made from engravings in *Industries*.



600 HORSE-POWER ELECTRIC PLANT EXHIBITED AT THE FRANKFORT EXHIBITION.

See preceding page.

THE INJECTOR.

By Professor R. C. Carpenter.

PART II.

THE range of action of the simple injectors described in the first part of this article and illustrated on the following pages is now nearly or quite as great as the more complex ones of earlier times, and in many respects, although without adjustable features, excepting the simple upper stories of the building. The tank from which the suction is taken is on a pair of scales and is connected to a similar tank also on scales; the discharge-pipe passes upward and then through a long coil of pipe situated in a tank of cold water, in order to reduce its temperature to or below that of the room; it is then received into a tank on a pair of scales and weighed. To re-

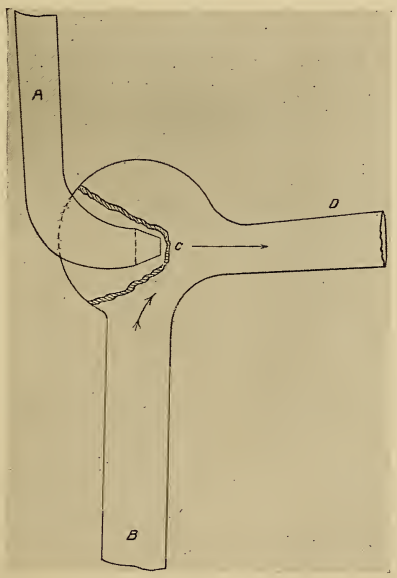
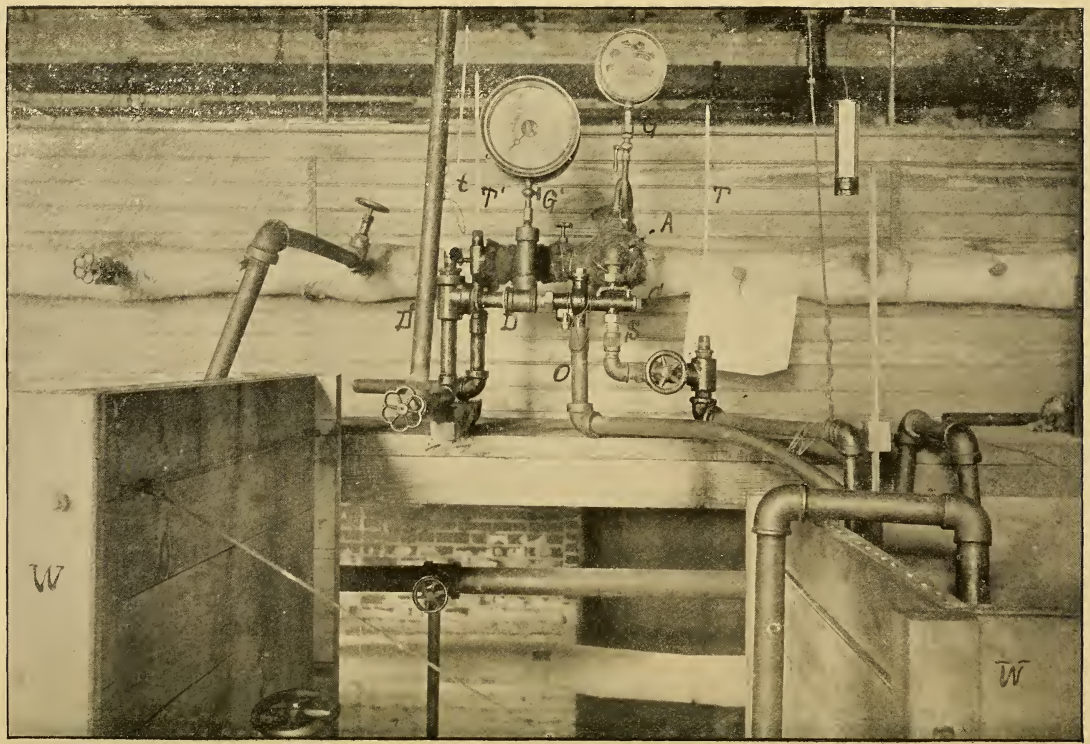


FIG. A.—THOMSON'S JET PUMP.

check-valve on the overflow, they are even more nearly automatic.

The apparatus used in making the tests appears in the illustration on the following page. The injector is located at *C*, *D*, steam is supplied through the pipe *A*, suction-water is taken through the pipe *S* from the tank *W*, the overflow is returned through the pipe *O* to the same tank; the water is discharged through the pipe *B'* to a tank in the

duce evaporation in the upper tank, the water is kept covered with a film of oil, as in some of the early experiments made it was found that the loss by evaporation, even when the temperature was reduced to 110° Fahr., was sufficient to make a large error in the results. The temperature of the water entering the injector is measured by the thermometer *T*, that of the discharge by the thermometer *t*, the pressure of the entering



APPARATUS FOR TESTING INJECTORS.

steam is measured at G; a sample is passed through a calorimeter and its temperature taken at T'; the gage G' is attached to an air-chamber, which is connected with the discharge. The pressure or head against which the injector worked was regulated by a throttle-valve in the discharge-pipe some little distance from the injector. The

the injector was determined as follows:

The injector was started, and after it had assumed the working condition to be maintained during the experiments a poise on the scale-beam of the scales carrying the suction tanks W, W was set slightly back of its balancing position; when a certain amount of water

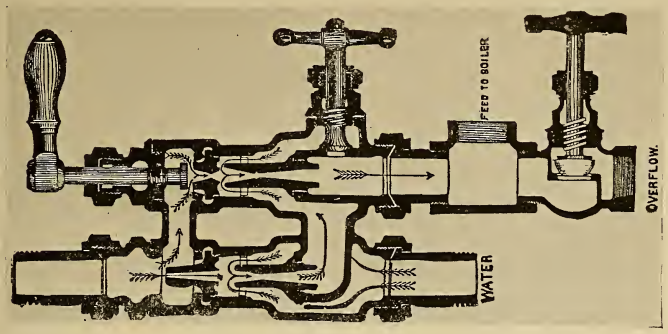


FIG. 6.—HANCOCK INSPIRATOR. MANUFACTURED BY THE HANCOCK INSPIRATOR COMPANY.

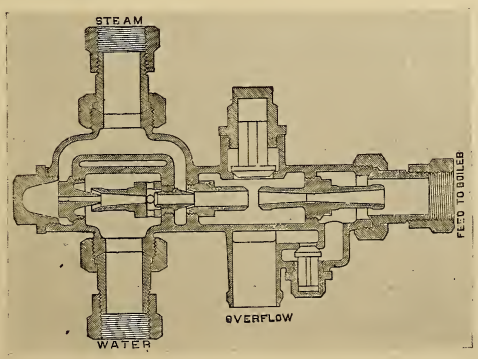


FIG. 7.—PARK DOUBLE JET INJECTOR. MANUFACTURED BY THE PARK MANUFACTURING COMPANY.

length of a single run was the time taken to pump the water held by the two tanks, W, to the delivery tank in the upper story. This amount was about 3000 pounds of water. The work done by

ran out, the scale beam tipped, throwing in contact an electric bell, which was a signal to the operator at the upper tank to commence to save the discharge which had been previously wasted. The

run was terminated in a similar way. The difference in weight between that received in the upper tank and that taken from the lower tanks was due to condensed steam. The condensed steam corrected for the percentage of water existing in it, as shown by the calorimeter, gave the weight of the dry steam used. The weight taken from the suction-tanks added to the entrained water in the steam was the weight of water lifted.

This multiplied by the distance corresponding to the pressure shown by the pressure-gage added to the suction height (each pound of pressure being equivalent to 2.37 feet at a temperature of 180° Fahr.) would be the work done in lifting the water. A similar calculation with reference to the steam used must also be performed, since the steam carries its own weight as well as the weight of the water.

This mechanical work absorbs a certain amount of heat, which may be expressed in heat-units by dividing by 778, it having been found experimentally by Joule and Rowland that the heat used in raising one pound of water 1° Fahr. in temperature is equivalent to lifting 778 pounds one foot, or one pound 778 feet.

There was a certain amount of heat lost in radiation, but this was diminished as much as possible by covering the injector carefully with hair felting. Assuming no loss from radiation, the amount of heat received by the injector should be just equal to that discharged by it, added to the heat transformed into external work as explained.

The heat received is known, since we measure the pressure and weight of the entering steam, and can obtain from a steam table the heat-units in each pound. This heat is used in warming a known weight of water from the temperature, as shown by the thermometer in the suction-pipe to the temperature shown in the discharge-pipe; this amount in heat-units is equal to the gain in temperature multiplied by the weight, added to the heat equivalent of the work as explained. As the radiation loss at best is a very small percentage of the whole, these quantities should be nearly equal; that is, the heat received should equal that discharged added to the work done, expressed in heat-units. This was well known before commencing the experiments, but we were hardly prepared for the erroneous results that were made in the early experiments before the discharge-pipe was run through a cooling-tank. These experiments, although made with much care, showed the heat discharged greater than that received, and consequently that the thermal efficiency of the injector was over 100 per cent. The cause of the discrepancy was found, after the two young men in charge of the experiment,

TABLE I.—EXPERIMENTS SHOWING WORK DONE BY THE INJECTOR AS A PUMP.

Steam pressure by gage. Pounds per sq. inch.	Delivery pressure by gage. Pounds per sq. inch.	Simple injector, fixed nozzles.		Double injector, nozzles in line.		Double injector, nozzles parallel.	
		Duty. Ft. pounds.	Water per horse power. Pounds.	Duty. Ft. pounds.	Water per horse power. Pounds.	Duty. Ft. pounds.	Water per horse power. Pounds.
12.5	10.5					430,710	4609
20	20	1,122,500	1781	1,037,515	1918	911,048	2173
25	2					298,820	6626
30	30	1,445,073	1364	1,261,609	1569		
40	2					213,160	9293
40	20	981,840	1602				
40	40	1,635,680	1210	1,553,921	1274		
45	45					1,722,273	1149
50	50	1,817,338	1089	1,914,044	1055		
60	10					166,003	11,927
60	60	1,791,595	1105	1,943,703	993		
70	10					161,506	12,246
70	20	762 665	2386			677,290	2923
70	40	1,661,675	1191			1,314,466	1506
70	60	2,404,757	823			1,987,965	996
70	70	2,256,000	881	2,176,422	909	2,262,840	875
70	80	2,320,000	853				
70	90					2,752,318	725
80	2					161,516	12,242
80	80			2,147,541	880	2,298.895	861

Mr. Burwell and Mr. Arnold, had worked several weeks, to be due to the evaporation of water in the discharge-tank, at a temperature not exceeding 110° Fahr. This amount we had supposed previously to be entirely negligible. The reason for the large error introduced by neglecting such a small factor depends on the fact that the weight of steam is a small quantity compared with the water lifted, say 6 to 9 per cent. The amount of steam was obtained by taking the difference in weights between that taken by the suction-pipe and that discharged, and any error made in these quantities would be a large *percentage* error of the steam. Thus, if the loss by evaporation is only true because all the heat discharged is usefully applied.

The equation expressing this would be:

$$\left.\begin{array}{l}\text{The total heat}\\ \text{received}\end{array}\right\} = \begin{array}{l}\text{heat rejected} + \text{work}\\ \text{expressed in thermal}\\ \text{units} + \text{radiation.}\end{array}$$

The heat rejected is all returned to the boiler; even the reduction in work caused by friction reappears in the form of heat and is transmitted to the boiler, and thus becomes of use.

In the case, however, the injector is not used as a boiler-feeder; then the only term expressing useful work is the actual

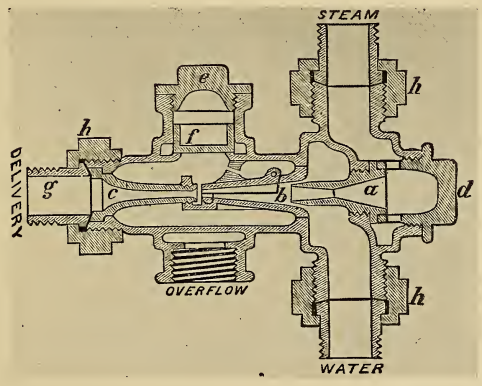


FIG. 8.—MANHATTAN INJECTOR. MANUFACTURED BY SHAFFER & BUDENBERG.

were one-fourth of one per cent. of the total weight, the corresponding error in the result would be from 3 to 5 per cent.

The result of these experiments makes us able to state *that every injector, good or poor, should give a thermal efficiency of 100 per cent.*, the only loss being that due to radiation, and the error of any test corrected for radiation is the amount which the test shows greater or less than 100 per cent.

THERMAL EFFICIENCY OF THE INJECTOR.

In the preceding pages the fact has been mentioned that the thermal efficiency of the injector was unity; this mechanical work performed, which, as will be shown in later tests, is a very small quantity compared with the total heat received, and the resultant duty of the injector as a pump is very low indeed.

A high duty as a pump has been thought possible by some because the steam acting on the water expands to a lower pressure, and consequently develops a large amount of mechanical work. It would seem, however, quite certain from our experiments, that, while such expansion may take place, condensation occurs so early that very little of the expansive force is available for the mechanical work of raising water.

THE INJECTOR AS A PUMP.

The work done by the injector acting as a pump is best shown by the following results of actual trial. The results are expressed in two forms : first, the duty which is the number of foot-pounds of work obtained by the consumption of 100 pounds of coal, each one of which is supposed to evaporate 10 pounds of water. Second, the number of pounds of water required as steam to deliver work equal to one horse power. It is perhaps well known that the duty of our best pumps in water-works stations varies from 100 to 140 million of foot-pounds. Small direct-acting pumps, such as the injector would perhaps compete with, have a duty from 4 to 8 million pounds. The water consumption per horse power per hour for the steam engine is well known to vary from 60 to 15 pounds, depending on the class and size. Direct-acting small steam pumps, such as the injector would compete with, have been known to require over 400 pounds per indicated horse power.

The experiments would indicate that as a pump the simple fixed nozzle injector was superior to the more complicated double ones, at least for lower pressures; and further, that the efficiency continually increases with the steam pressure, and with the pressure in the delivery-pipe. The following table shows the results of an actual test on several different injectors, made by Burwell and Arnold in the spring of 1891. The injectors were all of small size, having three-fourths inch pipe connections, and on account of the small size should be compared with a wasteful pump ; even in that case the best duty for the injector will not exceed 40 per cent. of that of a pump working under similar conditions.

MECHANICAL THEORY.

Besides the thermal efficiency, which is only concerned with the loss and transformation of heat, there should evidently be a mechanical theory to explain its action on different principles. Such a theory explains the action as the impact of a small body at high velocity—the steam in the steam tube—coming in contact with a large body moving in the opposite direction or at rest (the water in the suction-pipe) and giving a resultant velocity common to the entire mass, the water in the discharge-pipe.

The explanation is exactly similar to the striking of one ball against a larger one, resulting in the motion of the two balls as one with a common velocity. Thus if w′ is the weight of the steam, and such water as it may contain, and v

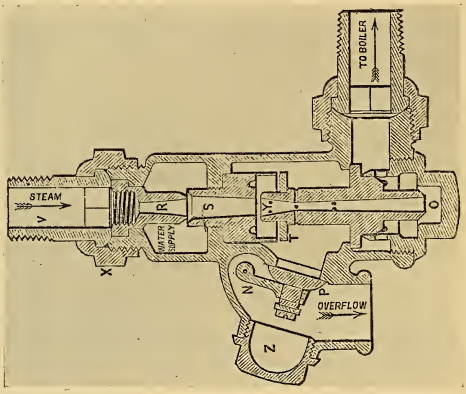


FIG. 9.—PENBERTHY INJECTOR. MANUFACTURED BY THE PENBERTHY INJECTOR COMPANY.

its velocity, its momentum is $w'v \div g = m$; if W is the weight of water lifted, and its original velocity deduced from the suction-head be negative and equal to V', its momentum is $W V' \div g = M'$; if V is the velocity of discharge, the common momentum is :

$$M = (W + w') V \div g$$

By the principles of impact,

$$\frac{w'v}{g} + \frac{W V'}{g} = \frac{(W + w') V}{g} \quad (1)$$

but because of loss of force by eddies and friction, w'v will be greater than the second member of the equation.

This may be reduced to a more convenient form, in which the area is expressed in square inches and the discharge in cubic feet per hour ; thus, let c be the cubic feet of water discharged per second, C the cubic feet discharged per hour, a the least area of the nozzle in square feet, and A the area in square inches. The velocity in feet per second :

$$V = \frac{c}{a} = \frac{C}{3600} \times \frac{144}{A} = \frac{C}{25A} \quad (2)$$

The velocity which water must have to overcome a given pressure can be calculated from the known laws of the

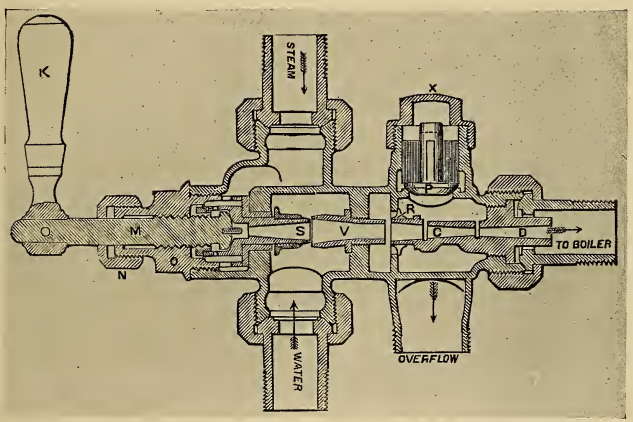


FIG. 10.—METROPOLITAN INJECTOR. MANUFACTURED BY THE HADVEN & DERBY COMPANY.

VELOCITY OF DISCHARGED WATER.

In order to find these various quantities we must know, or determine by observation, the weight of steam, the weight of water raised, the velocity of steam as it strikes the water, and the velocity of water in the suction-pipe and in the discharge-pipe. Knowing the weight of water raised at a measured temperature, its volume in cubic feet can be computed. The volume discharged per second, divided by the area in square feet of the least orifice through which it passes, will give its velocity in feet per second of time.

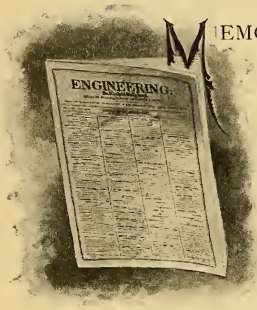
flow of liquid due to a given pressure, the velocity being equal to the square root of 64.3 times the head corresponding to the pressure to be overcome. The pressure to be overcome would be equivalent to a head of 2.37 feet of water for each pound, provided the water were at a temperature of 180° Fahr.

Thus to discharge against a boiler pressure of 80 pounds above the atmosphere the velocity must be greater than the square root of the product of 64.3 by 2.37 by 80, or about 111 feet per second.

(To be concluded in March issue.)

JAMES DREDGE: THE MAN AND HIS WORK.

By William H. Wiley, C.E.



MEMORIALS to distinguished men have been the subjects of much thought, and have frequently demanded the skill of some of the greatest artists. Many of the most beautiful works of ancient and modern times have been of this character, and vast sums have been bequeathed for this purpose. This article will deal with a memorial, but different from those alluded to, for it has been erected by the man it honors and represents his life-work. No greater or more enduring monument could be devised than the work of one who molds thought and who encourages genius by founding and conducting successfully for many years the foremost scientific journal of the age, read in both hemispheres, and recognized as a high authority, such as is *Engineering*, of London.

The proud position of founder and editor of this great paper is held by the subject of this article with so much modesty and utter absence of self-conceit that the man receives quite as much honor and far more affection than the editor.

James Dredge was born in Bath, England, July 29, 1840. His early training fitted him most admirably for his present position, since his father was a bridge engineer of eminence, one widely known in England some sixty years ago. Both he and his brother William followed their father's profession. William Dredge, whom the writer had the pleasure of knowing, was one of those kind-hearted, amiable men who drew a stranger at once to him, and who might be aptly described by the word lovable. He was considerably older than James, and died recently in England. The younger son was the pupil of the elder for some years, and there was between them a marked affection which lasted till the latter's death.

From 1858 to 1861 Mr. James Dredge was in the office of the well-known D. K. Clark, and this was the turning-point in his life, since it was here he met that brilliant but unbalanced American, Zerah Colburn, and his equally brilliant but more distinguished countryman, Alex. L. Holley. In Mr. Dredge's eloquent address delivered two years ago at the unveiling of the Holley statue, he speaks of the great impression made on his mind as a young engineer by this meeting. He declares with his usual modesty they seemed to him like "superior beings," and made him feel his own ignorance.

In 1862 he entered the office of that celebrated engineer now known as Sir John Fowler, and remained there three years, being engaged for the most part in the Metropolitan Railway system, side by side with one of England's greatest engineers, whose advice Americans think well to obtain at the present day,—Sir Benjamin Baker, who is known in America from his connection with the Hudson river tunnel, of which he is the consulting engineer.

In spite of the greatest difference of manner and thought, these two young men formed a life friendship, and are to-day most intimate. Their very difference seems to have been a bond of union, as the writer, who is a friend of both, can testify from personal observation. Their course in life separated when Mr. Dredge left the office, and each has become eminent in his career.

In 1866 Zerah Colburn *started Engineering*. The word is used with discretion, for it remained for his two successors to *found* this journal.

It was through his connection with *Engineering* that Mr. Dredge met his co-editor, Mr. William H. Maw, already

a mechanical engineer of eminence. Mr. Maw's clear head and indomitable energy, coupled with a perfect genius for hard and unceasing work, made him just the man for an associate in a new enterprise, and to-day Mr. Dredge attributes much of the success of *Engineering* to Mr. Maw's quiet and unostentatious manner of grasping an idea and carrying it to a successful conclusion, while Mr. Maw, on his part, would give equal credit to Mr. Dredge, for each one loves and admires the other.

Zerah Colburn's meteoric career came to an end by self-destruction in 1870, leaving *Engineering* without resources and without credit. In fact, he left only the name. Mr. Maw and Mr. Dredge then decided to put their shoulders to the wheel and extricate the paper from the mire. Associating with them Mr. Alexander T. Hollingsworth, who married a niece of Sir Henry Bessemer, these three formed a partnership with the happiest results, for it proved not only successful, but was the commence-



AMONG THE ELMS.

It is a source of much regret to Mr. Maw's American friends that he has never visited this country, and it is for this reason he is not so well known to us as his co-editor; but believing with true British conservatism (he is a Conservative) there is no place like England, he is quite content to be known by his brilliant editorials, and to entertain his American friends in an elegant manner in England rather than to give them the opportunity to entertain him in their country.

ment of an intimate and enduring friendship. Messrs. Maw and Dredge undertook the editorial work, and Mr. Hollingsworth the business management, for which his early training had fitted him, and to whom also the other two award the great success of the financial part of their enterprise. In fact, this partnership is an ideal one, and has lasted for twenty years, as one of the partners told the writer, "with absolute harmony," which certainly reflects the greatest credit on the three partners.



LOOKING TOWARD CLAPHAM LODGE.

Mr. Hollingsworth made his first visit to America last fall, and, as is usual with him, made many friends. He charmed us and was charmed with us and with our surroundings, so much so that he hopes soon to come again, a project which his friends trust he will carry out.

Last year this partnership was changed into a limited company, but this was merely a legal change, for each of the partners holds a third interest, and each conducts the same department as before.

The methods of relaxation of these three men may not be uninteresting. They are alike in one thing, and that is in splendid hospitality, but each has a different method of employing such leisure as he chooses to take. Mr. Dredge is devoted to amateur photography; he is also a great lover of nature, and is specially fond of flowers. He has fine greenhouses, and raises rare orchids. He lives at Clapham, some six miles from London, in a lovely house, with a park full of great trees. It is called Clapham Lodge, and here he welcomes his American friends with that rare hospitality which at once makes the visitor welcome and feel almost as if in his own house.



ENTRANCE TO CLAPHAM LODGE.

The entrance to Clapham Lodge is at the road running past Clapham Common. Passing the porter's lodge, the visitor goes under an archway of beautiful trees, shown above, until an iron gate is reached. On entering this, the beautiful view of the house appears as shown opposite, which unfortunately does not include the many greenhouses already alluded to. From these houses the visitor is regaled with cucumbers and melons, the vines being carefully trained to climb and the fruit tied on, something which strikes an American as a curiosity, and almost fills that sage's (?) idea who would have placed the pumpkin on the oak instead of the insignificant acorn. On the front of the house to the right is seen a conservatory, the interior of which appears in the illustration. The ferns are rare and beautiful and a little fountain in the miniature grotto plays into a basin full of gold-fish. Passing through the house the scene shown in the illustration opposite delights the eye of the visitor. The lake shown in the engravings affords pleasant relaxation by means of rowing, and at one time contained a variety of fish. At present golden carp are its principal inhabitants, except a flock of ducks and geese which live on the small island in its center. The dining-room opens upon a lovely lawn, the windows reaching to the floor. Mr. Dredge's love for flowers is well known to everyone on the place and each morning the gardener has a little buttonhole bouquet for him, as well as one for any guest who may be there. When Mr. Dredge last left for America, the last thing the gardener did was to present him with the usual bouquet, this time made of immortelles, which he said would last till his return. Is it any wonder that Mr. Dredge loves this spot?



THE LAKE IN SUMMER.

Clapham is just the place for rest and seclusion, and undoubtedly many columns of thought which appear in *Engineering* originate there.

Mr. Maw is also a lover of flowers, and he, too, has beautiful greenhouses and graperies, but his great pleasure is taken in astronomy and microscopy. He has probably the finest private telescope in the world and a complete observatory just in the outskirts of London, while his cabinet contains thousands of slides and a magnificent microscope.

Mr. Hollingsworth's taste appears when his guest visits his house, which contains a remarkable collection of oil paintings worth many thousand pounds. Like his partners, he entertains lavishly



THE LAKE IN WINTER.

and with great hospitality, and is ably seconded in this by a charming family, who have considerable musical ability, while he himself has a fine voice and much musical taste.

In addition to their labors on *Engineering*, both of the editors have written scientific works of great value. "Road and Railway Bridges," by Maw and Dredge, was the first; and in 1873 was issued the Report of the Vienna Exposition by the same authors. Professor R. H. Thurston, who can speak authoritatively of this, told the writer it was the finest report of any exposition, at the time of its issue, which had been made. After this report, which called their paper into special notice and from which its prosperity dates, each produced books separately. "The History of the Pennsylvania Railroad," giving working drawings of everything used in this great railway and full descriptions of the plant, was the work of Mr. Dredge in 1877, and was an embodiment of his impressions of our model railway as he saw it in 1876, when he was at our Centennial. In 1878 Mr. Dredge made an exhaustive report on the Paris Exposition, and in 1881 he issued the first volume of "Electric Illumination," which proved to be a great success. It was a large quarto volume, beautifully illustrated, and containing everything known at that time on the subject. The supply of books was soon exhausted, and copies now are very scarce, commanding a premium. Volume II brought the subject up to the date of issue, and these books form today the standard work on the subject. They are, in fact, a cyclopedia of electric lighting. Meantime, Mr. Maw issued his work on Marine Engines, a large quarto containing illustrations of the best marine practice in the world, with drawings of the engines and full descriptions. This work was also speedily exhausted, and is similarly a standard of the best practice at that time. Mr. Dredge next published a most elaborate report of the Paris Exposition of 1889, to which he was one of the most active and enthusiastic commissioners, and it should be mentioned that he guaranteed a large sum from his private funds in case of loss in the English exhibit. He spent months of his time in Paris, and bore all his own expenses, which were necessarily very great, finally closing his house in England and moving to Paris. His friendship with Sir Polydore de Keyser, Lord Mayor of London, who served as president of the British Commission in Paris, and to whom much of its success is due on account of his ability and great talent for organization, was increased by their intimate relations during this difficult period. In 1891 Mr. Dredge issued his latest work, "Modern French Artillery," containing a full account of all the latest French guns. This book has received great praise from artillery officers all over the world. Its author has received two decorations at the hands of the French government,—in 1878,

Officier de la instruction publique, and in 1889, *Officier de la Legion d' Honneur*.

The American Society of Mechanical Engineers made him an honorary member in 1886, and in 1890 the United American Societies selected him to deliver the memorial address at the unveiling of the Holley statue, a mark of distinction which he has always pointed to with the greatest pride, and a duty which he fulfilled in a manner not only justifying the choice of the committee, but



THE CONSERVATORY AT CLAPHAM LODGE.

highly gratifying to his friends and equaling their greatest anticipations ; and as a fact Americans have, with their usual appreciation of merit, whether at home or abroad, delighted to honor Mr. Dredge as one of England's noblemen, of whom all English-speaking people may be most justly proud. In 1890 he came to America and visited Chicago. He was so thoroughly impressed with the plans for the Columbian Exposition that he threw himself heart and soul into work for it at home, and it is due to his efforts that so much is known all over the world regarding this great undertaking. In the spring of 1891 the Queen appointed the Royal Commission, consisting of the Council of the Society of Arts, of which Mr. Dredge is a member, and in September of that year he came to this country as a royal commissioner, accompanied by Sir Henry Wood, who was secretary of the commission, although not, as many supposed, a member of it. These gentlemen went to Chicago, and made a joint report, which has resulted in new and more energetic measures in England to promote the British exhibit there. The first paper on this subject was read by Mr. Dredge to the Society of Arts, December, 1890, and resulted in the British Commission, while the second paper was read December 9, 1891, to the same body, and served to stimulate the interest already excited. These two papers were followed by one read January 12,



CLAPHAM LODGE, THE HOME OF JAMES DREDGE.

1892, to the London Polytechnic. All these papers were very elaborate and exhaustive in their treatment of the subject, and Mr. Dredge has laid the entire Chicago Commission under lasting obligations, which it is hoped they fully appreciate. As to the obligations of American engineers to Mr. Dredge, they are so many that only a few can be cited. He has done more to promote a kindly sentiment for us in England than all the interchange of courtesies combined. He has welcomed visiting Americans to his house and to all the clubs and societies of which he is a member. He has introduced them to just the men they wanted to meet, and has encouraged their contributions to the columns of *Engineering*. It was he who started the movement which resulted in that grand trip of the United American Societies to England in 1889, and to him was also largely due the credit of originating the magnificent reception given to them by the French engineers. Those engineers who took this trip understood to whom they were indebted, and yet it was all done in his usual quiet and unobtrusive manner, although the details, even to railroad transportation and special trains, were fully worked out by him in advance and sent to the writer before the party left America.

But the greatest service he rendered Americans, and especially American engineers, was when he had Alexander Holley taken from his hotel where he was sinking rapidly from disease and conveyed to his own house, where Mr. Dredge showered every attention on him and brought him back from the verge of the grave and thus lengthened that valuable life for several years, during which Mr. Holley perfected some of his greatest inventions.

Mr. Dredge is a member of the Savage Club, also of the St. Stephen's, and one of the Council of the Society of Arts. He belongs to the Scandinavian Club, likewise, but he has frequently said he considered as one of the greatest marks of appreciation he had received the conferring of honorary membership on him by the American Society of Mechanical Engineers.

In this pushing nation modesty is not appreciated, and it is to be feared that on this account Mr. Dredge has not been fairly judged, nor have we realized the friend America has and Americans engineers possess in him; indeed, he has been so pronounced in his friendship for Americans that many Englishmen suppose him to be an American. His motto has always been, "Duty before everything," and he has lived up to it. He has visited this country four times, and the writer, who knows him so well and esteems him so highly, is glad of this opportunity of paying this slight tribute to him, knowing that it will set vibrating a kindred chord in the hearts of the entire engineering profession and will bespeak for him a most cordial welcome when he again visits America as royal commissioner to the Columbian Exposition.

One of the new applications of aluminium is to the refining of other metals by the addition of small quantities of the first-named element, says an author in an English contemporary. It has thus been rendered possible to obtain cast-iron pieces of very superior quality. By the addition of aluminium the finely divided masses of oxide of iron present in the fluid iron, which unfavorably influence the solidity of the casting, are reduced; the very light alumina slag is driven upward in the molten metal and floats upon the surface. In view of the removal of the oxide of iron, the casting will result of a more compact nature from the fact that the carbon contained in the iron has no opportunity, by uniting with the oxygen of the oxide of iron, of forming carbonic acid, vesicules of the gas of which are left behind in the iron, leaving cavities. Copper castings are also refined in this manner. The addition of aluminium when smelting down old brass and other metallic scrap is recommended. In this case an admixture of 1 to 5 parts of aluminium to 1000 parts of the other metal is necessary.

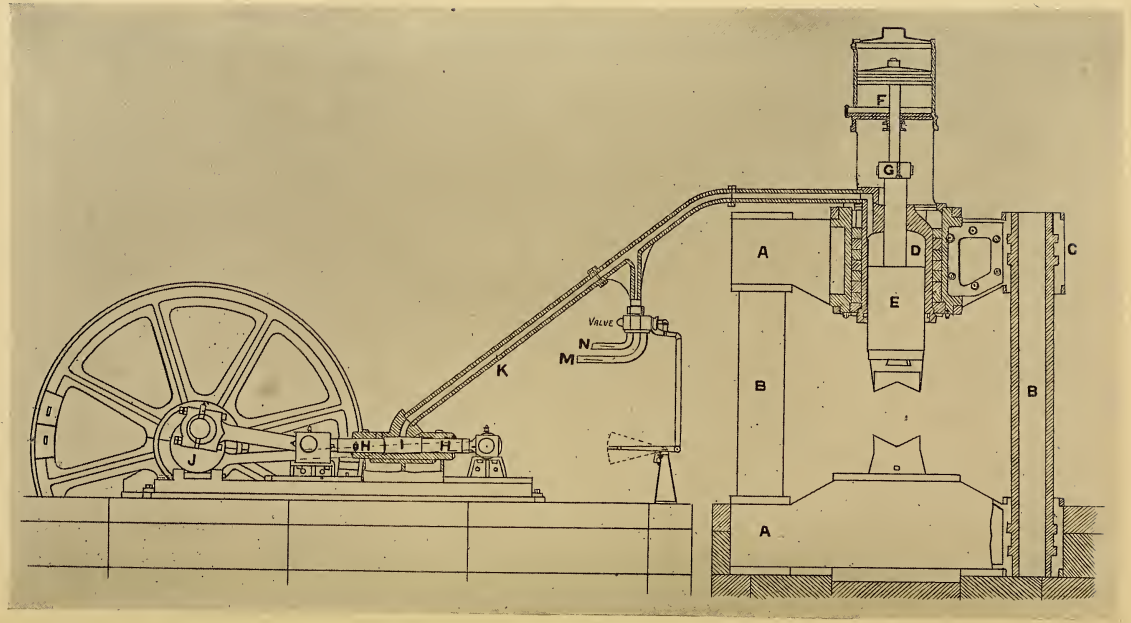


FIG. I.—NEW FORGING PRESS AND PUMPS.

THE FORGING PRESS.*

By W. D. Allen.



THE production of heavy forgings from cast ingots of mild steel make it necessary that the mass of metal should be operated on as equally as possible throughout its entire thickness. When employing a steam hammer for this purpose it has been found that the external surface of the ingot absorbs a large portion of the sudden impact of the blow, and that a comparatively small effect only is produced on the central portions of the ingot, owing to the resistance offered by the *vis inertia* of the mass to the rapid motion of the falling hammer, a disadvantage that is entirely overcome by the slow, though powerful, compression of the hydraulic forging-press, which appears destined to supersede the steam hammer for the production of massive steel forgings.

The press now brought under notice was designed to act more or less automatically, or self-acting, and to insure the perfect parallelism, both of flat or square masses, and of round shafts, without being dependent for their truth on the skill of the operator. The forging-press about to be described has been erected and in operation for some time. It works most satisfactorily, and, on the whole, is found to be a most efficient and useful tool. In this press the force-pump and the large or main cylinder of the press are in direct and constant communication. There are no intermediate valves of any kind, nor has the pump any clack-valves, but it simply forces its cylinder full of water direct into the cylinder of the press, and receives the same water, as it were, back again on the return-stroke. Thus, when both cylinders and the pipe connecting them are full, the large ram of the press rises and falls simultaneously with each stroke of the pump, keeping up a continuous oscillating motion, the ram, of course, traveling the shorter distance, owing to the larger capacity of the press-cylinder.

Fig. 1, on page 292, shows the press and pumps. The top and bottom portions of the framing *A*, *A* are alike, and from the same pattern, each consisting of two castings, held by bolts and steel hoops, as shown. The main columns, *B*, *B*, are hollow; they have angular projections or rings, *C*, *C*, cast at each end, which fit into corresponding recesses, cast in the top and bottom frame pieces. The large press-cylinder *D* is fitted and held in the top frame; the anvil block rests in the bottom frame. Weldless steel hoops are shrunk on to the cylinder to give additional strength. *E* is the main ram. It has a strong shank to it, which passes through the top of the cylinder, acting as a guide. *F* is a steam-cylinder with piston, the piston-rod of which passes through the gland at the bottom of the cylinder, and is attached to the shank of the ram. *G* is a cross-head working in guides, thus preventing the ram from turning round. The force-pumps may, perhaps, be appropriately termed "duplex," the ends or facers of the two plungers, *H*, *H*, advancing and receding to and from each other simultaneously at each stroke. They work into the opposite ends of the pump-cylinder *I*. This cylinder has no bottom, and becomes simply a strong tube. The two plungers are worked by the three-throw crank *J*, the two side-throws of which are on exactly opposite centers to the middle throw. The two side-throws give motion to the plunger farthest from the crank, in which case the strain exerted is a pull; whilst the middle throw gives motion to the plunger nearest to the crank, and the strain is a thrust or push. By this arrangement it will be

* Paper read before the Iron and Steel Institute, England.

observed that an absolute balance of force is obtained, and all strains between the crank and pump are avoided.

As before observed, a free communication is at all times maintained between the pump-cylinder and the press-cylinder. This is done through the pipe *K*, and when all are full of water, and the engine working, an ascending and descending motion is imparted to press the ram at each revolution of the crank, the descending motion being given by the press-plungers, *H*, *H*, advancing toward each other and forcing the contents of the pump-cylinder into the press-cylinder, the ascending motion taking place by means of the steam-piston, which, on the return-stroke, raises the ram, and forces the water back on to the pump-plungers as they recede from each other, so that as long as there is no waste of water by leakage, and its quantity is not increased or decreased, the press-ram will continue to oscillate at the same distance from the anvil, and could only operate on work of that exact size. The ram has, therefore, to be raised or lowered to suit the various requirements of work in hand, and to effect this a source of supply of water under a pressure of about 250 pounds has to be provided, which, when admitted into the press-cylinder, has sufficient force to overcome the power of the steam in the steam-cylinder, sending the steam back into the boilers. By this means the ram is rapidly brought down any required distance; on the other hand, the power of the steam immediately raises the ram upon the water being allowed to escape.

The valve used for the rapid admission and escape of water becomes, therefore, rather an important feature, and is shown in Fig. 2. It consists of a cylindrical casing, having a hollow cylindrical valve or plunger, working endwise through hydraulic leathers; at each end of this valve or plunger very fine slits are sawn lengthwise through its sides or walls. The principle of the valve is, the allowing of the admission and escape of water through the fine slits, by moving the valves endwise until the fine slits pass the hydraulic leathers; the set of slits at one end of the valve being for the admission of water, and those at the other for the escape. *L* is the casing bored through and fitted with hydraulic leathers, as shown. *M* is the inlet, *N* the outlet, and *O* the passage into the pipe *K*. The valve or plunger is fitted pretty freely into the casing, and is capable of being easily moved endwise. It is hollow, with a solid division in the center, the hollow forming a sort of cup on each side of the solid part, and through the side-walls of these cups the firm slits are cut. When it is desired to bring the press-ram down, the valve is moved endwise to the left until the fine slots pass the hydraulic leather, and a passage is thereby opened from the inlet *M* through the slits, and water is admitted into the passage *O*, and then on to the pipe *K*, and the ram at once descends. When it is desired to raise the ram, the valve is moved to the right, and water passes out through the other set of slots, and away by the outlet *N*, and the ram at once ascends by action of the steam.

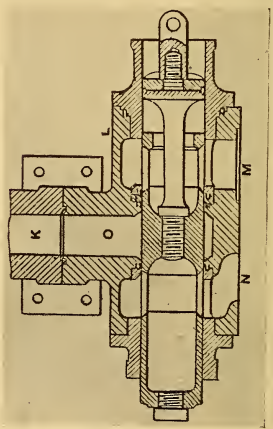


FIG. 2.—THE VALVE.

It should be observed that at the time the slits pass the leather the low pressure only is in operation, and at the moment of impact of the ram upon the work the valve is always in its neutral position, the position shown in the diagram, the plain body of the central portion of the valve, with a cup leather on each side, being all that is exposed to the great

pressure. The proper time for the admission of additional water is when the pump-plungers are receding from each other, and the valve should always be put in its neutral position before the ram-face comes upon the work. This arrangement of valve is found to operate most successfully, and the change of position of the ram is effected as quickly as is necessary or desirable. The valve, being in perfect equilibrium, is most easily worked by a handle, brought to a convenient position for the operator to see the work in hand. The ram may be raised or lowered for its entire range in a very few seconds. It can be brought down to the greatest nicety a little lower each stroke, enabling forgings to be made correct to dimensions, or in case of any sudden occurrence, when it is found undesirable for the impending pressure to take place, the stroke can instantly be averted by moving the valve to the right, although the face may even be in contact with the work. The ram, in fact, is perfectly under control, and almost as lively as the tup of a hammer. An accumulated power is obtained by two heavy fly-wheels on the crank-shaft of the pumps, the momentum of which imparts very great force at the moment of impact of the ram, at which time the cranks approach and turn their centers.

As a security against accident, and a precaution against this force becoming too great, a system of safety-valves has been devised, though not shown in the illustrations. It consists simply of a steam-cylinder and piston, the piston-rod of which works into a small hydraulic cylinder that is in constant connection with the pipe *K*. Steam is admitted into the steam-cylinder at the opposite end to that of the piston-rod, and when the hydraulic pressure on the end of the piston-rod becomes sufficient it forces the steam back into the boilers. Thus, if the steam-piston is 60 inches in diameter, and the piston-rod 6 inches in diameter, and the pressure of steam 50 pounds per circular inch, a hydraulic pressure on the end of the piston-rod of 5000 pounds per circular inch will be an equivalent, and a pressure exceeding that will force the steam back into the boilers, and relief for the water will thereby be obtained.

The press-ram makes a stroke of 2⅞ inches, and its diameter is 30 inches, so that at a pressure of three tons per square inch (deducting the area of the shank) we have a power of 1700 tons. But, of course, no pressure is developed until resistance takes place; hence no power is lost or consumed, except what is lost by friction, until the ram-face comes into actual contact with the work, and then sufficient pressure only is developed and consumed to do the work. The press was fitted up by W. & J. Galloway & Sons, of Manchester, and, with the exception of the steam-cylinder *F*, it is constructed entirely of steel. The form and strength of all the parts have proved to be capable of sustaining the sudden and great strains to which they are subjected, and no springing or flinching takes place—the ram always descending to the same spot, whether it has to press 2 inches into an ingot, or has nothing to do. This has been found manifest in rounding-up, for when the ram is once brought down to the right point to give the required diameter, the work has only to be regularly turned round. Of course all has to be dead-tight, but there are no joints except cupped leather ones, and those are very few.

MONS. J. GARNIER, Paris, France, has recently patented a new process for the manufacture of metallic nickel, says an exchange. It consists in purifying the crude nickel resulting from the reducing fusion of nickel oxide or roasted nickel mattes by charging the crude nickel with the addition of coke and lime, magnesia, or baryta, together with fluorspar or sea-salt in a water-jacketed furnace having a basic lining or a lining of chrome-iron ore, the bed of fusion being so prepared that the bases enter into the slag formed in the proportion of 75 per cent. to 25 per cent. of silica and fluorspar or silica and sea-salt, the product obtained consisting only of nickel and the metals of the bed of fusion, viz., iron, and sometimes copper from which the sulphur, arsenic, silicon, and phosphorus have been eliminated.

THE PRODUCTION OF ALUMINUM. I.

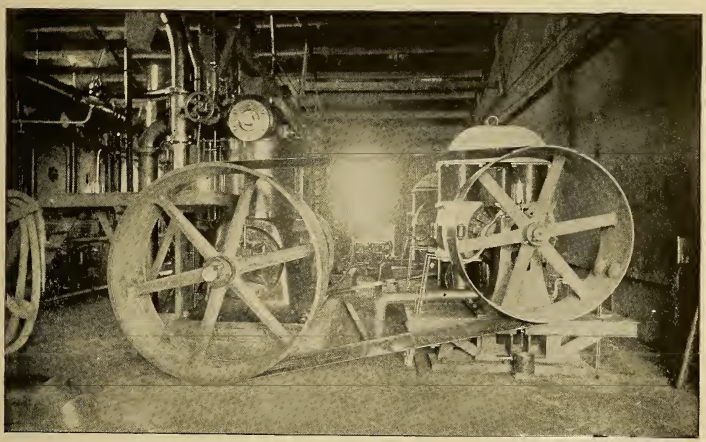
By E. P. Allen.

AS from a utilitarian standpoint the past is significant only in so far as it throws light on the present, and as the present study of the subject of aluminum is entirely from the utilitarian standpoint, we will not follow the more usual method by commencing at the birth of the aluminum industry, but will first describe the most approved modern, or, since the whole matter is modern, the most approved present practice, and then haste back to its antecedents. From certain data, which will appear, it may be accepted that it is to electrolysis we must look for "cheap aluminum." Again, of electrolytic processes, that which is generally known in this country as the Hall (or fluoride) process, invented by Mr. C. M. Hall, of Oberlin, O., and now owned by the Pittsburgh Reduction Company, of Pittsburgh, Pa., has clearly the *pas*.

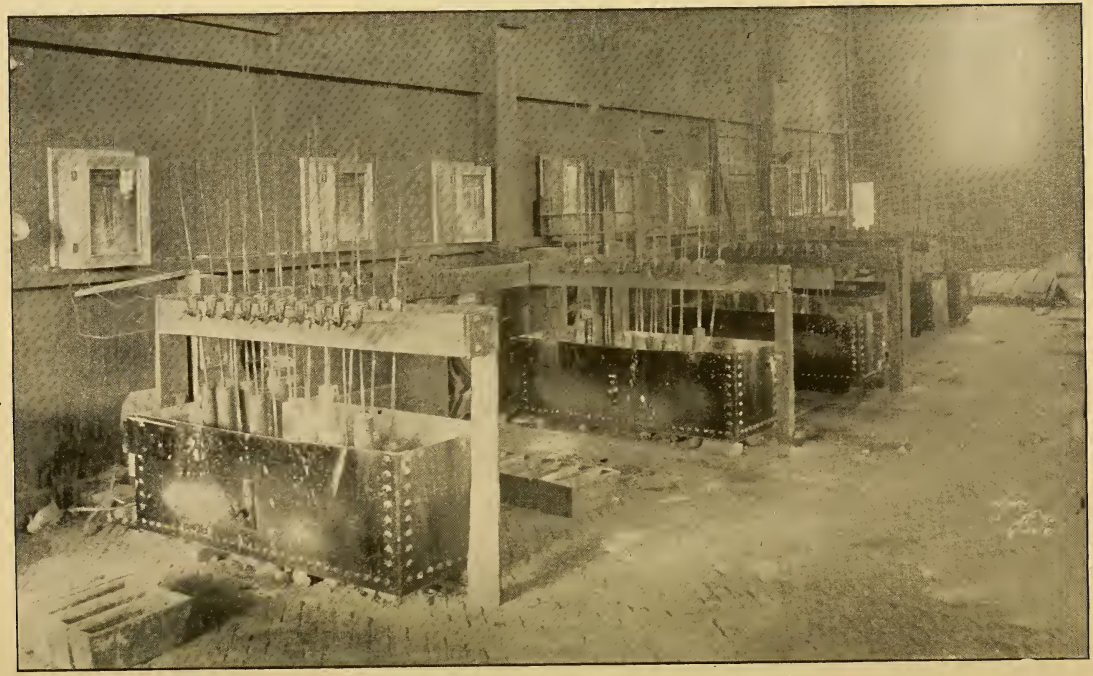
The works of the Pittsburgh Reduction Company were until recently in the Lawrenceville mill district at Pittsburgh; they are now removed to Kensington, a newly-plotted town, some eighteen miles up the Allegheny river. The inducements to removal were, by the way, proximity to gas and coal, as a second resort, and a free site under certain conditions. The Lawrenceville plant is in all probability simply removed and not changed, so that we shall still be describing actualities. The company in its experimental stages operated a small plant capable of turning out some 50 pounds of aluminum per 24 hours. The experiments having proved successful and the company having been formed on its present basis, in the spring of 1889 the plant was much enlarged. The addition, complete in itself, and the practice in connection with it, will form a convenient example to our hand of the operation of the process in question. It consists of two Weston dynamos specially designed for this purpose by the United States Electric Lighting Company, of Newark, N. J., of 2500 ampères and 55 volts each, run by two Westinghouse compound engines of 250 H. P. each, and supplying current to six electrolytic pots through appropriate connections. The dynamos are connected in multiple arc, thus yielding a current of 5000 ampères by 55 volts; the pots are connected in series, so that the whole current passes through each pot at an average tension of 9 volts. Nine volts are much more than sufficient for effecting the decomposition of alumina, which requires only 2.8 volts, and for overcoming the transfer resistance a small item. The surplus energy is converted into heat in fusing the bath and maintaining the fusion. The materials worked upon, in the simplest form of the process, are cryolite and alumina, the latter not in any one of its native states or combinations, but as an already finished product of a chemical works, an anhydrous oxide containing the least possible percentage of impurities. But on the subject of ore, more hereafter.

It is impossible to speak accurately beyond this point without paving the way with a reference to a question of theory. The electrolysis of fused masses is a subject of such recent growth that it has so far had very little thorough study. It is a subject of many inherent difficulties. It is not a simple matter to discover reaction or other operations in a molten mass, though, to be sure, there is very little firm ground in any sort of electrolysis. In the present case there is a question as to whether the cryolite—rather, its aluminum fluoride constituent—or the alumina is the electrolyte; that is to say, whether the cryolite acts simply as a solvent of alumina and the latter is directly decomposed, or the aluminum fluoride in the cryolite is decomposed and continually regenerated by the combination of the fused fluorine with the aluminum of the continually added alumina. There is much to be said on both sides, and authorities differ. Among inventors, Hall and Héroult, judging from their patent specifications

and subsequent utterances, consider that alumina is the electrolyte and that the cryolite plays simply the part of a solvent, possessing in addition to its remarkable power of solution the advantage of a lower specific gravity than that of aluminum, thus allowing the molten metal, as it is separated, to collect in the bottom of the pot or preventing its rising to the top in the nascent state and recombining with oxygen in burning. Minet, on the other hand, believes that the fluoride is the electrolyte, and the alumina, continually added, regenerates the bath, and Minet, it would seem from his learned papers in French electrical journals, is more competent to express an opinion than his confrères. Outside of the art, among American authorities, Professor Richards, of Lehigh, follows Hall, and Dr. Wahl, secretary of the Franklin Institute, follows Minet. The considerations which lead to the former position may be found in Professor Richards's book, "Aluminium," and strong arguments on the latter side may be found in an article by Mr. A. H. Buchern which appeared in the *Engineering and Mining Journal* of June 6, 1891. From a practical standpoint it is necessary to choose a position on this question only in order to prevent a confusion of terms. Thus, following Minet, we will speak of cryolite as the electrolyte and will consider that the function of the alumina dissolved therein is to regenerate aluminum fluoride. Under this theory the sodium fluoride of the cryolite would seem to be passive. Starting, however, with the conception that alumina is directly acted upon by the current and that the other constituents of the bath are merely solvents bringing the alumina into that peculiar state in which alone it will succumb to the influence of the current, Hall considered that the best solvent was the best bath, and set to work to improve this solvent power. To this end he changed the proportion of aluminum fluoride to sodium chloride existing in cryolite by adding a certain quantity of the former, prepared by treating alumina with hydrofluoric acid. He further added a quantity of calcium fluoride (ground fluorspar) to increase the fluidity of the bath. Whether or not this mixture is an improvement, has not yet had final proof, but, so far, it has appeared that the Cowles Electric Smelting and Aluminum Company, at Lockport, N. Y., in their experience with the fluoride process, have had less trouble in working with the simply cryolite bath than the



ENGINE AND DYNAMO ROOM, PITTSBURGH REDUCTION COMPANY.



REDUCING POTS IN OLD FURNACE ROOM OF THE PITTSBURGH REDUCTION COMPANY.

Pittsburgh Reduction Company have had with the Hall mixture.

To return, then, to the fluoride process at the point of our digression, we will take, for the sake of simplicity, if for no other reason, a bath of cryolite, to be regenerated continually by the addition of alumina. As molten cryolite is an excessively corrosive agent the electrolytic pots, usually of wrought-iron boiler-plate, must be lined thickly with carbon, which is little affected. The carbon lining is composed of carbon dust (as a measure of economy the stumps of the carbon anodes may be ground up for this purpose) made into a mass by means of tar, and carefully baked in the pot to a thickness of some six inches. It is essential to secure a close joint between the carbon and iron for the sake of uniform electrical connection, and to prevent cracks in the carbon by which the bath may reach and cut the iron. In the Pittsburgh practice the working space in the pots is some 36″ x 18″ in area by 8″ in depth. The negative electric connection is made to the pot itself, thus constituting the pot the cathode in the operation; the anodes are plural, being carbon "plugs," cylinders 18″ x 3″, attached to copper rods which are clamped to copper arms extending over the pot. As a rule, as many plugs are used as can conveniently be crowded in, side by side, in three or four rows. The clamps connecting the rods and arms mentioned are movable and allow rapid shifting or exchanging of plugs, or raising and lowering to accommodate the distance between the poles to the changes of the bath's resistance; these changes are due to changes in the composition of the bath, due in turn to lack of alumina, to imperfect mixture of the alumina with the cryolite, or other causes. In ordinary working the cathode and anode are but a few millimeters apart.

In "starting a pot," the two poles are brought together (*a*); the plugs are set in contact with the bottom of the pot. Cryolite (or the Hall mixture) is piled about them, covering the bottom. The dynamos are then started, and the cryolite is melted by electrical heat. It takes several hours to accomplish the fusion, and if the process were not continuous and the starting of a pot a rare occurrence, it would, of course, be more economical to melt the electrolyte in a crucible or other furnace and charge it when molten. As the electrolyte melts in the pot, alumina is added. When the bath thus made is a consistent fluid mass, it is the part of the potman to keep it supplied with alumina to a point near saturation. The electrolyte, being regenerated continually by alumina, remains nearly constant. It is rarely that cryolite has to be added. If it were possible to keep the bath quite constant, there would probably be very little else to do but keep up a proper supply of alumina, but the nature of the process and of the materials entails inequalities of working, and consequent changes of resistance, as mentioned above. Each series of pots is therefore provided with a volt-meter, on which, at intervals, a reading is taken for each pot, which is then treated according to the showing thus made. The change of resistance is generally an increase, and when working with Brush dynamos, as at Lockport, the alteration is at once apparent by the excessive sparking of the machines owing to a backing up of the current.

OUTPUT AND DYNAMOS.

Working with the dynamos of the United States Electric Light Company, which seem so far to show the greatest efficiency, the highest average output of each pot in a series of six, for 5000 ampères, at an average tension of nine volts per pot, has been 75 pounds per 24 hours. The question of grammes deposited per electrical H.P. hour and comparison with the theoretical yield per Watt hour must be left to a theoretical investigation. It may be suggested, however, that the theoretical yield must be different if aluminum fluoride is the electrolyte from that which is to be expected if alumina is the electrolyte. In general, practical terms, other things being equal, the output depends on the efficiency of the electric machine. The choice of dynamos is, therefore, of prime importance. The size of the pots employed depends on the number of ampères, since the larger the current the larger the amount of electrolyte which can be acted upon at

one time ; the number of pots in series, on the other hand, depends on the number of volts. If x equals the volts, and if nine volts be assumed to express the resistance of each pot, the number of pots for a given machine may safely be $\frac{x}{9}$. A pot may be so large as to be difficult of handling and working ; on the other hand, while one man can "tend" quite a number of small pots, too great a number of small pots will entail too great a loss of heat by radiation. By experience only can the proper means be determined, and the factors —ampères and volts—of the dynamo depend on this determination. The factors of the Weston dynamos at Pittsburgh have been given ; two Brush machines of the Cowles Company at Lockport, coupled in the same way, give nearly similar results, viz : in fair running, about 5600 ampères by 60 volts. This proportion seems to work economically so far as the pots are concerned in both instances ; but each type of machine presents its peculiar faults. The Brush machine must be stopped at frequent intervals to allow change of burnt-out tips. The burning of the tips is increased by the apparently unavoidable and frequent changes of resistance in the pots. The loss of efficiency is greater than the apparent time loss, the actual loss being increased by cooling of the pots during stoppage and the loss of energy in "bringing them up again." The efficiency of the Weston dynamo while it lasts is far greater, but in its case also the unequal working of the pots causes trouble, aggravating the liability of the armature to burn out, a liability which seems already peculiarly great under the existing proportion of ampères to volts. It was many months after the first machine was started that an armature could be brought to stand more than five weeks running under the very trying demands made, it being required to do work twenty-four hours in the day and seven days in the week. Careful arrangement of the wires in winding and more effectual insulation at dangerous points, as, for instance, when the bunches of wires are overlapped in leading them down to the commutators, have done wonders. Still, it is obvious that measures must be taken to secure, if possible, automatic adjustment on the part of the dynamo to fluctuations of resistance in the outer circuit. The application of dynamo electric machinery to the electrolysis of fused masses is so new a thing and the progress already made is so satisfactory that it seems very probable that all the difficulties in the way will soon be removed. Before leaving the subject of dynamos we may mention that the Crompton machine has been used with fair results in England by both the Cowles Syndicate Company, Limited, of Milton, in Stoke-on-Trent, in the Cowles alloy process, and by the Metal Reduction Syndicate in the Hall process ; the Héroult companies at Neuhausen, Switzerland, and Boonton, N. J., have used a machine constructed by the Oerlikon Machinen Fabrik, at Oerlikon, in Zürich ; and the newly-organized Willson Aluminum Company, with works at Leaksville, N. C., will use in their alloy process a machine designed by Mr. Willson, the inventor of the proces, and built in Brooklyn. This last machine, presenting some novel features, has recently been described at length in electrical journals.

HISTORY.

Having in the fluoride process as described a point of view, we may more intelligently follow the developments of the aluminum industry up to the present practice, and look into the present attitude of the competing companies toward each other, and the commercial status of the metal. A word or two in regard to the name. The word aluminum or aluminium is derived from *alum*, since from the mineral alum, the commonest variety of which is a double sulphate of aluminium and potassium, alumina (Al_2O_3, the only known oxide of aluminum, analogous in name to *silica* and *soda*) was first separated and recognized as a distinct metallic oxide. The stem of the Latin word *alumen* is *alumin;* the choice of termination depended entirely on the analogy which prompted it. In its chemical nature the new metal was seen to be closely allied to the metalloids silicium (silicon), sodium, potassium, etc. Governed by this consideration, chemists generally, and especially abroad, where this influence is

apparently more strongly felt, have preferred the ending *ium*, and called the metal "aluminium." Practical considerations, on the contrary, make for a name more in analogy with those of the useful metals, among which the newcomer will rank. We therefore follow the American procedure in choosing the form aluminum in the same category as caprum, ferrum, platinum, aurum, etc. Again, much confusion has arisen from an ill-advised and wholly unnecessary attempt to distinguish aluminum from its alloys by dubbing the former "pure aluminum," so that aluminum is "pure" even if it be but



MELTING-HOLES IN THE OLD FURNACE ROOM OF THE PITTSBURGH REDUCTION COMPANY.

97 fine. Aluminum bronze is no more aluminum than brass is copper; we will therefore call each by its name, reserving the epithet "pure" until such time as aluminum can be turned out as pure as, for instance, pure copper is. Tons of the metal have been turned out by the fluoride process over 99 fine, and even averaging 99.25, but only a few hundred pounds have ever exceeded 99.75.

The meager history of aluminum—for, in spite of a voluminous patent literature, the bulk of which has no value whatever except to a psychologist, the history *is* meager—has been the subject of so many newspaper paragraphs that it scarcely need be repeated. Briefly, after the first recognition of alumina as a metallic oxide by Margraff in 1754, or Baron in 1760, and the formation of aluminum chloride by Oersted in 1824, Wöhler, in 1827, separated aluminum from the chloride by treating with potassium vapor, but obtained the metal in the form of a fine infusible powder. Not till 1854 did Deville obtain a button by passing the chloride as a vapor over molten potassium. Such names as Davy and Bunsen and Percy must be added to the list as of those who threw more or less light on the subject by their experiments. St. Claire Deville, however, must be considered the father of the industry. There is hardly a modern development which he did not foreshadow (see his book published in 1889), and he first attempted to produce the metal on a commercial scale. Deville's earlier work is well described by Professor Richards in the *Cosmopolitan* of January, 1892. Professor Richards's book, "Aluminium" (Philadelphia, 1889), is also a mine of information, or, rather, a depository of many minings, particularly in the historical and theoretical field, but it must be said that therein much is published without criticism which had already received too much honor of publication in letters pat-

ent. The work of Deville and his contemporaries was in two lines, one chemical and the other electrical. Owing to the expense and inefficiency of the crude electrical apparatus of the day, the chemical processes received the greatest attention and the first development. In the only chemical processes which have had success sodium is the active agent, and they may therefore be called sodium processes. They are two: in one aluminum is reduced by sodium from its chloride, in the other from its fluoride. The first has had something of a career under the operation of the Aluminum Company, Limited, at Oldbury, England, and the Alliance Aluminum Company at Newcastle-on-Tyne. The second is the Grabau method, and has been practiced for some years in Germany. The value of these processes depends primarily on the cost of the sodium employed, and since, according to the formulæ, $Al_2Cl_6 + 6\ Na = 2\ Al + 6\ NaCl$, and $Al_2Fl_6 + 6\ Na = 2\ Al + 6\ NaFl$, it takes at least 3 pounds of sodium to liberate 1 pound of aluminum, it is something of an item. Great attention therefore was paid to the cheapening of sodium. Mr. H. Y. Castner, formerly of Philadelphia, by a modification of the old process of reducing the sulphide by iron gained a great step, which led to the formation of the company at Oldbury. The Netto process employed by the Alliance Company differs from the above chiefly in an apparatus allowing a measure of continuity, which always adds to the economy of a process. Grabau obtains his sodium by electrolysis of common salt, using one carbon and one iron electrode. Since the lowest cost of sodium yet achieved is 14 cents (Grabau), and of aluminum by a sodium process one dollar, it is apparent that the comparisons above named have now no chance against those employing the fluoride electrolytic process. The Aluminum Company, Limited, long ago recognized that fact, and no doubt both it and the company at Newcastle will soon devote themselves exclusively to the production of sodium for other purposes. For some time those employing the sodium processes, having to do with purer materials, were able to claim the production of purer metal, but that time has passed, owing to improvements in the purification of alumina, as will appear.

The electrical process of Deville consisted of the electrolysis of aluminum chloride or fluoride in a bath of double chloride or fluoride of aluminum and sodium, double fluoride being cryolite. This bath might be regenerated by the addition of alumina in either of two ways: first, in the shape of cakes, made up with tar as a binder, and placed in the bath to be gradually dissolved thereby (thus early in the discovery of the solution of alumina by the bath, so much insisted upon by Hall & Héroult), and, second, again in the shape of cakes, or of cylinders, but used as electrodes, which equally are gradually dissolved by the bath. This plan has lately been tried with fair success by the Cowles Company at Lockport (see proceedings in Pittsburgh Reduction Company *vs.* Cowles Electric Supply and Aluminum Company, suit for damages on account of infringement); it, however, did not seem to find much favor in the early days, and since the electrodes were usually copper, the process was adapted only to the production of alloys of aluminum and copper; the aluminum being freed at the negative pole was deposited thereon and the coated electrode being removed and melted, the alloy was formed.* The process, word for word as described by Deville in 1859, was patented in France by his pupil, Le Chatelier, in 1861, and communicated by him to Bell, English patent of 1862. This is probably the process employed by Sir I. Lowthian Bell for some years near Newcastle-on-Tyne, of which city that distinguished metallurgist was mayor in 1863. It was worked there

* The failure of all electrolytic processes for producing aluminum on a commercial scale, until recent years, is to be ascribed, first of all, to the fact that early inventors tried to keep their bath fused by applying heat externally, and did not rely, as in the present practice, on electrical heat alone. They therefore employed only so much current as, by their calculations, was sufficient to decompose the electrolyte and to overcome the transfer resistance. This worked well enough in laboratory experiments to mislead in the larger practice. Mr. Hall, for instance, spent a year in attempting with external heat what, after its abandonment, was accomplished in a few months.

for the sake of aluminum bronze (discovered by Dr. Percy in 1855) until 1874, when the great expense of electricity at that time led to its abandonment.

Given cryolite as a bath regenerated by alumina in aluminous electrodes, we have something not unlike the modern fluoride process, but it must be said for the later invention that Deville touched very lightly indeed on the use of cryolite, and does not appear to have had the slightest conception of the significance of his suggestion. Again, the constant addition of alumina by hand now practiced, which forms the principal means of the economy of the present practice, was not proposed by Deville, and certainly not done by him. Finally, as far as can be gathered, the process was never successfully used by Deville or his followers for the production of aluminum unalloyed. There can hardly be any doubt, however, that later inventors have received their first impulses from Deville's suggestions. The time was ripe for a new and successful development, and, as is usual under similar circumstances, two men simultaneously, though in different parts of the world, arrived at the same idea. In principle the Héroult process in Germany and the Hall process here are identical. Hall's modifications of the bath are immaterial, but whether the Hall patents must stand or fall by those modifications is a question for Judge Ricks, of the Northern Circuit of Ohio, to decide. M. Héroult is a young French chemist who, however, brought his eggs to a German market. To operate his process was formed the *Aluminium Industrie Actien Gesellschaft*, with works at Neuhausen, in Switzerland, on the Falls of the Rhine. This company is magnificently backed by the *Allgemeine Elektricitäts Gesellschaft* of Berlin, which latter has a paid-up capital of $4,000,000. The *Aluminium Industrie Actien Gesellschaft* has branches at Frôges (Isère), in France, and at Boonton, N. J. M. Héroult is patentee also of an alloy process identical with that of the Cowles brothers, but of that later. The company at Neuhausen derives power from the Falls of the Rhine, and by aid of this cheap power it is able practically to control the European aluminum market. In France there is an import duty on aluminum of five francs per kilogram, which probably occasioned the establishment of the works at Frôges. The Pittsburgh Reduction Company of Pittsburgh, Pa., works at Kensington, Pa., own the Hall patents, and have a branch at Patricroft, Manchester, England. Besides these companies employing the fluoride process may now be mentioned the Cowles Electric Smelting Company, works at Lockport, N. Y., a company formed to operate the Cowles alloy process, and whose embarkation on the fluoride process for aluminum in January, 1891, occasioned the suit on charge of infringement brought by the Pittsburgh Reduction Company.

This brings us to the present status of the aluminum question as regards the attitude of the various companies toward each other. The conflict between Héroult and Hall began in the United States Patent Office, where both had applications pending at the same time. Héroult was able to show that his application to the German patent office was anterior to any application made by Hall, but as the United States Patent Office does not accept any foreign evidence other than patent-office records, a letter of Hall's, describing his process and bearing date anterior to that of Héroult's application in Germany, carried the day for him. But, apparently, this interference suit is to be regarded as merely a preliminary test, for a statement made by the president of the Pittsburgh Reduction Company that the United States Aluminum Metal Company was estopped from producing aluminum was answered by Dr. Barnard, president of the latter company, to the effect that his company could not, in any sense, and would not, be prevented from working the fluoride process by the Pittsburgh Reduction Company. It would appear that the claims of the several patentees cannot be settled without recourse to law. The suit, Pittsburgh Reduction Company *vs.* Cowles Electrical Supply and Aluminum Company, has been mentioned. The Cowles Company, in practicing the fluoride process, do not use the Hall mixture, and their answer to the charge of in-

fringement is, in brief, that the Hall patents do not cover the use of cryolite pure and simple. In the outcome of this case the status of the Hall patents will be settled. In the preliminary hearings of last spring and summer, the injunction prayed for was not granted, but the Cowles Company was ordered not to increase its then output, and not to cut a price which should be fixed by the complainant in affidavit filed with the court, all of which means that the judge wished matters to remain *in statu quo* until the final decision should be rendered. The case is most interesting both in itself and because it is no doubt only the first of a series which shall finally result either in more complete monoply or in opening the fluoride process of producing aluminum to the world. While the Pittsburgh Reduction Company is suing the Cowles Company for infringement of the Hall process, the Cowles Company in turn is complainant in a suit against the Pittsburgh Reduction Company on account of infringement of the former's claim to the general application of electrical energy to the "smelting and reduction of ores." To their claim we will return after a consideration of the Cowles and kindred processes.

(To be concluded in the March issue.)

OBSERVATIONS OF A MECHANICAL ENGINEER.

By D. Ashworth, M.E.

THOSE who simply look as a matter of course upon the motive power of a plant or department fail to realize the enormous waste continually repeating itself almost at every point. At the same time they exercise the utmost vigilance and executive power in thorough economical management in all other departments.

The expert meets with two classes that come under this head. The first is the proprietor who does not claim to know anything about mechanical detail, and generally is engrossed with a multitude of outside affairs. Under these conditions matters of a mechanical character are placed in the hands of a foreman, thence to an engine-driver, whose knowledge may be limited to opening and closing a valve and shoveling coal.

The second is the one who knows it all. This class is legion in ordinary-sized manufactories, and is occasionally met with in some of the largest plants in the country. In the former class this condition is generally the result of having a single eye to the product, and to accomplish this the manager, who, in the majority of cases, is the proprietor, fully exemplifies the idea that all that is necessary is to have "the wheels go round," and so the waste goes on with the regular grind.

In the office, affairs are carried on with scrupulous exactness. A sharp eye is kept upon material to be operated upon,—the time and labor of the operatives are so systematized as to bring this feature to a matter of exactness and perfection and beyond peradventure,—while the pay-roll is scrutinized with Argus eyes never ceasing, and should its proportions expand beyond the lines determined by profit and loss, how quick the pruning-knife or remedy is applied. With all this, still the kettle boils, and the "wheels go round" in the usual way.

If competition becomes sharp, and it generally does, the question as to why I have such narrow margins or am running at a loss, is forced upon them, and a review of the points of management already touched upon takes place, and it seems that all has been done that can be done, when some one with a grain of common sense intimates that there might be some improvement made in the motive-power department. Never thought of that! Of course not. Why? Simply because the "wheels go round."

Did it never occur to this party that the tinkering on an old rattle-trap engine was a source of loss, or that 45 pounds of steam used per hour, when it should not exceed 30, was a true percentage in loss of so much coal and that

much money? Now, had that been in material, stock, etc., how soon it would have been halted.

What about the waste at the boiler? What proportion of heat went up the stack instead of generating steam? "What!" he exclaims, "do you mean to say that it is possible to absorb the greatest amount of power (fuel) by undue friction of shafting alone just to make the 'wheels go round'?"

With some such impressions created, a spasmodic effort is made to reform. But to whom shall I look for advice in this matter? In many cases, but not in the majority, the intelligence of the engineer in charge comes into play, but the greater number do not have such an adjunct, but simply a stopper and starter, who is very often the fireman as well.

What should he do? Now, ask him what course he would pursue in case the financial end of the business involved legal points, how quickly the answer would be, "My attorney." In case of sickness, who else but the physician? And so in cases such as cited, and not by any means overdrawn, the services of an expert in the special line should be called into play, and far better in advance than when the case is in its last stage, and very frequently is this the case after a great expenditure of time and money in attempting to accomplish an absurd impossibility, the fallacy of which could have been pointed out at once by a competent party.

I know now of a party who is pursuing this very course of making preparations for an experiment. When the preparations are completed, an opinion as to the merits of the case will probably be asked for. Notwithstanding the existence of these conditions, the cases cited are becoming less every year. Through the medium of the trade journals, which reach the many special branches, a vast amount of plain, practical experience, data, and information has been conveyed to manufacturers, the tendency of which as an educator has fostered the desire for more accurate as well as profitable results, and suggest the query, "Why should I not do the very best? Why not shake off the old and put on the new?" The lately reconstructed planing-mill, with modern appliances, and our modern flour-mill, give goodly token of the advance.

The natural desire to economize in fuel is becoming so general that economy tests of steam-plants are being constantly called for. This will increase with the sharp competition, keeping pace with the advance of intelligence in all our manufacturing industries, establishing the profession of mechanical engineering as prominent and permanent as the ancient professions of law and medicine.

One of the anomalies which is very often met by the mechanical engineer is the inordinate attempts to obtain advice and authentic information without the remotest idea that such is entitled to proper compensation. This is generally termed curbstone practice. A well-known mechanical engineer cited a case of this kind which came under his practice. A proprietor of an iron and steel works called, occupied over two hours in obtaining verbal data as to proper proportions for furnaces, and, when done, with the usual "much obliged," took his departure. There are some really good people who do this without considering for one moment that it is the quintessence of smallness. These same people would never think of pursuing such a course with an attorney or physician. Now, why this difference? It certainly cannot be that the profession, as understood by the public, does not carry with it the result of mental training and requirements as important as the older professions.

Another feature which borders upon the humorous is the calling in of the expert engineer when the remains are laid out, as it were. Properly speaking, this might be termed a "crowners' 'quest"; but no, something must be done to keep the wheels going, at least for the time being. Everyone knows how indefinite that term is and how often it is repeated. Upon this point, happily, progress is being made. First-class plants, from their earliest conception, are carefully designed, constructed, and erected by competent engineers, from thence slowly but surely embracing the lesser undertakings, which leads the writer to think that the time is not far distant when it will be the exception to do otherwise.

ANCIENT AND MODERN ROTARY ENGINES.

By Professor Jamieson, M. Inst. C.E., F.R.S.E., The Glasgow and West of Scotland Technical College.



THE very first invention of which we have any record connected with the production of motion by the aid of steam was in the form of a rotary engine. In a work entitled *Spiritalia Seu Pneumatica*, written by Hero, a philosopher of Alexandria, in Egypt, about the year 130 B.C., a rotary steam engine called the Æolopile is clearly described.

the piston, combined with the motions of the connecting-rod and crank, involved a considerable loss of power in transmitting the motion of the piston to the crank-shaft. Quite independent, however, of this mistaken idea, the apparent simplicity of deriving rotary motion *direct* from a rotating cylinder or piston has encouraged inventors to devise many kinds of rotary engines. The difficulty of putting their ideas into practical shape, and of keeping the internal moving parts steam tight, as well

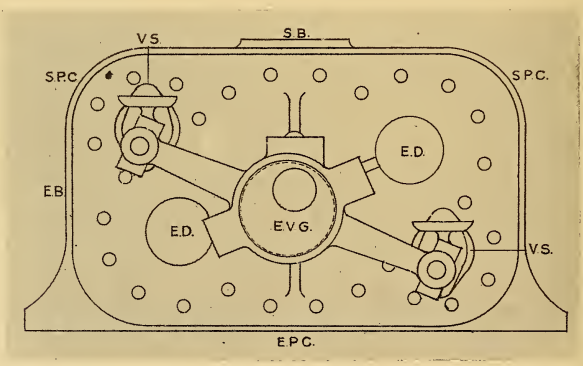


FIG. 1.—END VIEW.

S. B.—Steam branch to boiler.
S. P. C.—Steam passage casing.
E. P. C.—Exhaust passage casing.
E. B.—Exhaust-branch.
C. C.—Cylinder-covers.
B.—Bearings for shaft.
S.—Shaft.
V. S.—Valve-spindles.
E. V. G.—Eccentric valve-gear.
E. D.—Exhaust-door (end bearings).

Ever since steam-engines became useful machines, the rotary form has exercised a wonderful fascination over those of an inventive turn of mind. Many persons have tried their skill at producing them, with the view of superseding or at least successfully competing with the ordinary form of reciprocating piston engine. This fascination was at one time no doubt partly due to a prevalent belief that the reciprocating motion of

as of taking advantage of the expansive property of steam, has produced a general belief that patentees of rotary engines should be classed with those who imagined that they had discovered "perpetual motion" or the "philosopher's stone."

The various types of rotary engines hitherto produced have been clasified under the following headings: Reaction engines, impact engines, liquid-press-

ure engines, disc engines, and revolving piston engines.

The Æolopile described by Hero, of Alexandria, with such modifications as "Barker's mill," the "revolving gas-jet," and the fireworks "star wheel," come under the first-class, since their rotatory motion is derived from the reaction of the atmosphere against the force of an issuing fluid. The efficiency of these instruments is so very small, that little further use is made of them than in the form of models for the amusement of children, and as aids in the demonstration of natural philosophy problems on the principle of reaction.

Engines of the second class, such as Branca's, Pilbrow's, Cordis & Schiel's turbines, receive their motion from the impact of steam either directly at right angles upon or obliquely against revolving vanes. The Hon. Mr. Parsons's well-known steam turbine (of which a specimen was at work in the late Glasgow International Exhibition) belongs to this class. Many of his engines are at present employed for driving the electric lighting dynamos on board steamers, and four large ones, of over 100 horse power each, have been used for the past two years at the Newcastle and District Electric Lightning Company's Central Station. The high speed at which these steam turbines work (sometimes up to 10,000 revolutions per minute, in the case of small ones) enables them to be coupled direct to dynamos, and the combination thus occupies a minimum of space and of weight for the power developed. We have yet to learn, however, that their consumption of steam per B.H.P. hour is such that they can successfully compete on open terms with the best reciprocating piston engines, when space and weight are not of vital importance.

Of the third, or liquid-pressure type of rotary engine, many varieties have been tried, but none of them have been successful. Watt in his early career constructed an engine of this kind, in which steam acted against the weight of a column of fusible metal, but when the engine was stopped, the fusible metal, in the act of cooling, expanded (like water in freezing) and burst his cylinder. Neither mercury nor fusible metals have as yet been found suitable liquids in

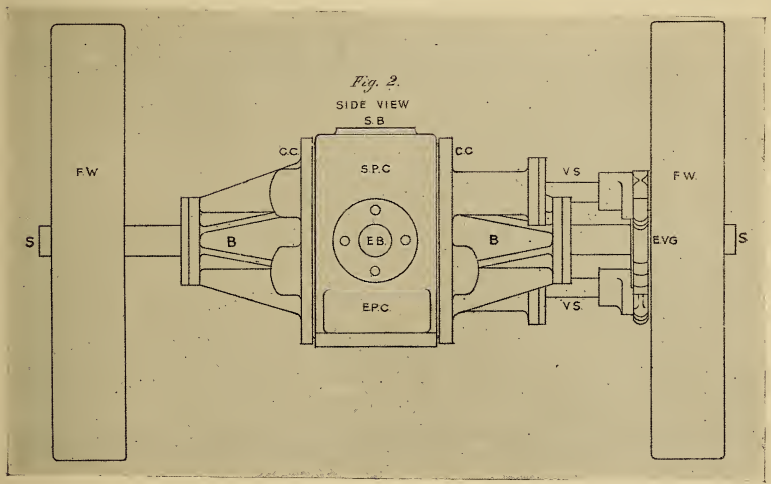


FIG. 2.—SIDE VIEW OF BROWN'S "DOUBLE DOOR" ROTARY EXPANSIVE ENGINE.

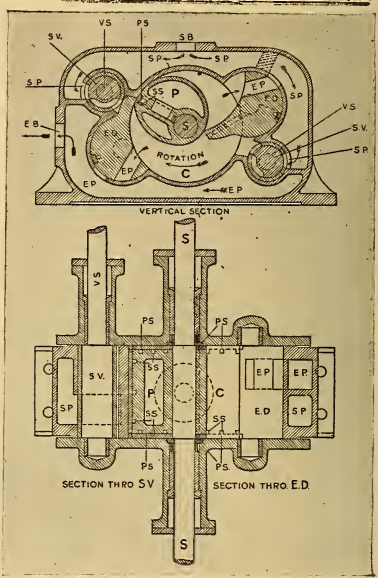
practice for obtaining motion from their combination with steam.

Disc engines (of which Bishop's and Davies's are the best-known forms) consist of a disc moving in part of a hollow spherical vessel, with a central outstanding arm attached to a disc or crank. No apparent economy has been observed with this form of engine over the simpler reciprocating piston, and the great difficulty experienced in keeping the internal parts steam tight led to their abandonment. They are mere frolics of mechanical ingenuity.

The most popular type of rotary engine has undoubtedly been that of the revolving piston. James Watt, Murdoch, Lord Cochrane (the Earl of Dundonald), David Napier, and John Yule, both of Glasgow, devised revolving piston engines.

The Earl of Dundonald was undoubtedly the most successful of the early projectors of this kind of engine, and had he been able to procure sufficiently accurate fitting mechanism, he would not in all probability have had to give up this pet project of his, at which he had worked so long and so hard. Within the last ten years or so an engine of this class, termed the "Tower Spherical Engine," has been extensively applied to the driving of dynamos and other fast-speed machinery without the intervention of gearing. In fact, the "Tower" and "Parsons" engines have of late held the field against all similar rivals. A great opportunity still exists, however, for the employment of a really economical rotary, which shall at the same time combine the other very necessary qualifications of neatness, small bulk, lightness, strength, durablilty, uniformity of speed under widely different loads and pressures, perfect balancing in all the moving parts, with freedom from noise and vibration.

Fully four years ago Mr. A. F. G. Brown (of Swindridgemuir, Dalry, Ayrshire), with the object of producing such a perfect rotary engine as has just been indicated, took as his prototype what he considered would most likely fulfill his object,—the revolving piston devised by James Watt and improved upon by the Earl of Dundonald. With this design as a basis he felt convinced that by the aid of the superior machine tools and workmanship now obtainable, and by making certain reforms in the mechanical details, he should meet with success. After constructing with his own tools and hands the working model, the dimensions of the cylinder of which were 4½ inches diameter by 2½ inches broad, giving 2½ B.H.P. at 930 revolutions per minute, with steam of 40 lbs. initial



FIGS. 3 AND 4.

INDEX TO PARTS.

S. B.—Steam branch from boiler.
S. P.—Steam-ports and passage.
S. V.—Steam-valves.
V. S.—Valve-spindles.
C.—Cylinder.
P.—Piston.
P. S.—Packing-strips.
S. S.—Spiral springs.
S.—Shaft.
E. D.—Exhaust-doors.
E. P.—Exhaust-ports and passages.
E. B.—Exhaust-branch.

pressure, he sought the aid of Messrs. John Lang & Sons, of Johnstone, whose skill in the manufacture of lathes and of shaping machines is well known to most mechanical engineers at home and abroad. The several engines made by Messrs. Lang & Sons were subjected to long continuous severe runs at full power

under a brake-load. Every detail which showed signs of weakness was redesigned and reconstructed. During the last twelve months I have had frequent opportunities of testing Mr. Brown's engines with a view to verifying his results and of suggesting wherein they might be still further improved, and thus I am able from personal observation to state that during this period the consumption of steam has been reduced by over 25 per cent., and that the durability and adaptability of the engine have been considerably enhanced.

From an inspection of the end and side views (Figs. 1 and 2) and their cor-

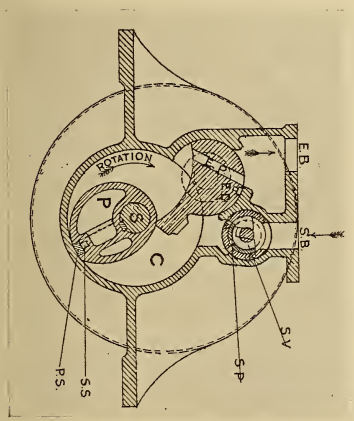


FIG. 6.—VERTICAL SECTION.

responding "index to parts," it will be seen that the engine consists of a cylinder encased in steam and exhaust-jackets, having strong end covers terminating in long bearings supporting the central shaft, to which are keyed a fly-wheel at each end. The eccentric valve-gear, which works the rotating valve-spindles, is shown on the end view.

From the accompanying sectional elevation and plans (Figs. 3 and 4), with their "index to parts," the internal arrangement of the engine will be readily understood. Steam from a boiler enters through a stop-valve and the steam branch SB into the steam passage, SP,* and through the steam-port in the left-hand revolving steam-valve, SV, into the cylinder, whenever the piston, P, has passed the nose of the left-hand oscillating exhaust-door, ED. The piston is thereby forced round under full steam-pressure until it reaches the point of "cut-off," when the left-hand rotating valve closes the steam-port. For the remainder of the stroke, the piston is propelled by the natural expansive force of the steam (enclosed between it and this steam-valve) until release takes place through the exhaust-port, EP, in the boss of the right-hand exhaust-door, ED; from whence the steam passes along the exhaust passage, EP, and through the exhaust branch, EB, to the atmosphere or to a condenser according as the engine is working as a non-consing or condensing one. Precisely the same action takes place during the remaining half of the piston's revolution by aid of the right-hand steam-valve and the left-hand exhaust-door.

Nothing could be simpler under the circumstances, or more effective; for full advantage is taken of the expansive properties of steam by so arranging the "lead" of the eccentric (which turns the steam valves) that the "cut-off" may take place at any desired proportion of the piston's stroke; or the "cut-off" may be directly varied according to the load and steam-pressure by connecting a loose eccentric to the governor.

It will be observed that the front edges and surfaces of the exhaust-doors make a steam-tight fit with the circumferential surface of the piston, and that when these doors are closed they form part of the bore of the cylinder. They are forced forward by the incoming steam pressing behind them, whenever the peculiarly-shaped piston has passed them, and they are pushed *gently* back

* This steam passage thus forms a steam-jacket to half the cylinder. It may be arranged so as to form also a "water-trap" (with a return "loop" to the boiler) so that nothing but dry steam shall enter the cylinder. The underneath side of the cylinder is steam-jacketed by the exhaust steam. The outside of both cylinder covers and jackets is carefully lagged with felt, and covered with wood to prevent radiation.

into their seats by the piston (during expansion and release) against the reaction of the pent-up or "cushioning" steam retained between them and the steam-valves.

The working surfaces of the piston, steam-valves, and exhaust-doors are all packed by gun-metal strips, kept up to their bearings by small adjusted spiral springs. From the perspective view of the piston it will be seen that the side and end packing strips are checked into each other, as well as the side-strips into the ring ones next the shaft. In order to make the wear uni-

jacketed, as it is intended for rougher and smaller work than the double-door one, such as driving fans, etc.

In the last test made I carefully measured the volume of the boiler water-supply tank, and found it to be 305 lbs. for the barrel when full to the overflow hole; I checked the brake-spring balances by government-stamped standard weights; saw that the brake-ropes were properly adjusted, and found the radius of the brake-load (r) to be 2.0417 feet.*

With steam shut off from the engine, the feed-water was forced into the locomotive multitubular boiler by the in-

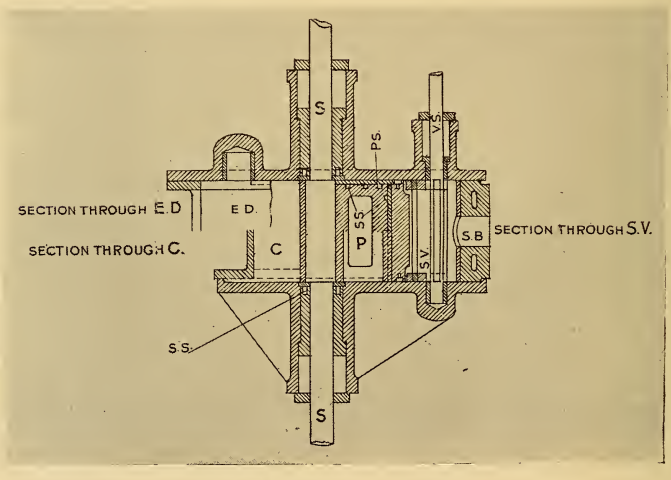


FIG. 7.—SINGLE-DOOR ROTARY ENGINE.

form on the side packing strips, the spiral springs are made proportionately shorter, the further they are from the center of the shaft, and since each of these springs is contained in the same length of hole, their outward pressure on their strip is inversely proportional to their radial distance from the center of the shaft; or, in other words, inversely to their travel.

From the description just given of the double-door engine, the construction and action of the single-door type will be easily understood from Figs. 6 and 7. This form of engine has not been steam-

jector until it reached a definite mark (about half glass) on the polished brass scale, fixed immediately behind the gage-glass. The water-supply tank was then filled up to the overflow hole, and the steam-pressure raised to 93 lbs. by steam-gage. The engine was started at 2.15 P.M., at a speed of 560

* Hence, log. of constant for B.H.P.

$$\left(\text{or log. } \frac{2\pi r}{33000}\right) = 4.5895$$

log. of mean brake pull, 93.2 lbs. = 1.9694
log. of mean speed, 574.5 = 2.7593
log. of mean B.H.P., 20.8 = 1.3182

revolutions per minute, and then simultaneous observations were taken every 15 minutes of the boiler-pressure, net brake-load, and the revolutions per minute by Messrs. Schaffer & Budenberg's tachometer, the accuracy of which I had previously ascertained by trial with a speed counter, from which the brake horse-powers have been calculated. The whole of my observations have been inserted in the accompanying table exactly as they were written down at the time, and the means are taken from the continuous run extending over five hours.

small, right-angle bends, and the non-effective water-trap. From the indicator-cards taken by me prior to commencing the brake horse-power trial of 5 hours, as well as from those taken by me subsequently on the 4th of June, the indicated horse power was 25.1 lbs. per I.H.P. hour. Had I been certain that the brake-wheel (which was 4 feet in diameter with light arms) could have withstood a higher speed than 600 revolutions per minute, there would have been no difficulty so far as the engine itself was concerned in increasing the speed to 800 or even 1000 revolutions

BRAKE HORSE-POWER TESTS OF BROWN'S ROTARY ENGINE.

Dimensions of Cylinder and Piston.—Diameter of cylinder = 10.5 inches; length of cylinder = 8.625 inches; volume of cylinder = 746.9 cubic inches; cross area of piston = 40.5 square inches; length of piston = 8.625 inches; volume of piston = 349.3 cubic inches, or nearly equal to half the volume of the cylinder.

No. of reading.	May 27, 1891. Times. p.m.	Boiler pressure by gage, lbs.	Net brake-load, lbs.	Revolutions per minute.	B. H. P.	Remarks.
1	2.30	93	90	560	19.58	Each barrel full of feed-water = 305 lbs.
2	2.45	90	84	570	18.61	2.50 p.m., 1st barrel into boiler.
3	3 00	93	87	580	19.61	.....
4	3.15	93	88	580	19.84	.....
5	3.30	93	92	580	20.73	3.25 p.m., 2d barrel into boiler.
6	3.45	93	92	560	20.02	3 45 p.m., 3d " " "
7	4.00	93	92	550	19.66	.....
8	4.15	93	90	570	19 04	4.10 p.m., 4th barrel into boiler.
9	4.30	93	92	570	20.38	.....
10	4.45	98	97	570	21.49	4.35 p.m , 5th barrel into boiler.
11	5.00	93	93	570	20.60	.....
12	5.15	96	96	580	21.64	5.05 p.m., 6th barrel into boiler.
13	5.30	96	96	580	21.64	Engine very steady. Brake working splendidly.
14	5.45	98	98	580	22.09	5.25 p.m, 7th barrel into boiler.
15	6.00	100	96	600	22.39	5.45 p.m., 8th " " "
16	6.15	97	99	560	21.54	6.10 p.m., 9th " " "
17	6 30	93	94	570	20.82	6.30 p.m., 10th " " "
18	6.45	93	93	600	21.69	.....
19	7.00	99	102	570	22.08	6.55 p.m., 11th barrel into boiler.
20	7.15	98	93	590	21.32	7.20 p.m., 12th " " "
						7.40 p.m., 13th " " " less 16½ lbs.
			93.2	574.5	20.784	Total feed-water used in 5 hours = 3948.5 lbs.
	Means =	95				Gross feed-water per hour = 789.7 "
						" " per B.H.P. hour = 37.9 "
						" " per I.H.P. hour = 31.47 "

From this table it will be seen how very steadily the engine maintained its speed, and how the power developed by it gradually rose from a minimum of 18.6 B.H.P. to a maximam of 22.39 B. H.P., as the working parts warmed up. A considerable condensation of steam no doubt took place in the steam-pipe, and in the two long indicator-pipes, which were not lagged. The fall of pressure between the boiler and the cylinder, as shown by a comparison of the pressure-gage, and the indicator-cards, amounting to fully 15 lbs. to the square inch, is due to the steam-pipe being

per minute; as both the material and workmanship seemed to be of excellent quality, and the only oscillating parts were the valve-doors, which were duly cushioned during their back-strokes, and always kept bearing upon the rotating piston by steam acting from behind them. Had this higher speed been attempted, there can be no doubt that the consumption of steam per B.H.P. hour would have been still less than it was, viz: a mean of 37.9 lbs. per B.H.P. hour.

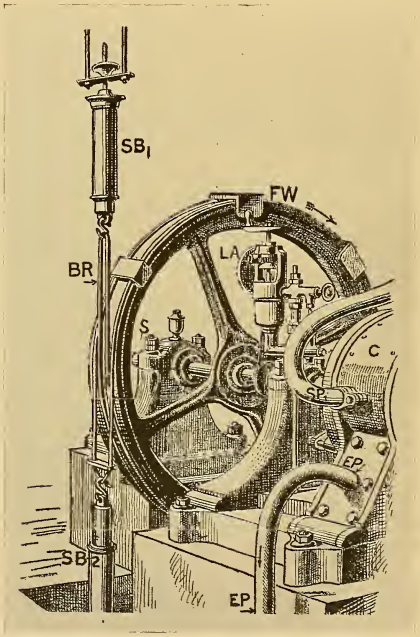
It was found impossible to get steady cards at the high speeds maintained during the brake horse-power trials, owing

to vibration and jerking, so I had to be reluctantly content with cards taken at 200 revolutions per minute.

The indicator diagrams were taken with M'Innes's fast-speed indicator, and they are remarkably good. They show an almost equally effective power developed by the steam admitted through each rotating valve and cylinder-door. The mechanical efficiency of the engine and combined heavy brake-wheel and gear, or ratio of brake horse power to indicated horse power, was 80.8 per cent.*

After steam was shut off from the engine at 7.15 P.M. feed-water was injected into the boiler until it reached the same mark on the gage-glass scale with which we started the trial run, and the feed-water barrel was filled up to the overflow hole. From these data I found that the engine had used a total of 3948.5 lbs. of water during the 5 hours, or 789.7 lbs. of water per hour, which is equivalent to 37.9 lbs. per B. H.P. hour and 31.74 lbs. per I.H.P. hour. Since these tests were taken by me the engine has been so improved that Mr. Brown obtained (with one steam initial pressure of 89 lbs. [per square inch and 600 revolutions per minute) 24.25 B.H.P. on a consumption of 33 lbs. of steam per B.H.P. hour. This would give with 81 per cent. mechanical efficiency (assumed from former results) under 27 lbs. of steam per I.H.P. hour.

I had the right-hand cylinder cover removed after the five hours' run, and found all the working surfaces in perfect order. Not only were the original tool-



GENERAL VIEW OF ENGINE.

* Or, $\frac{\text{B.H.P.}}{\text{I.H.P.}} = \frac{20.784}{25.1} = 80.8$ per cent.

marks everywhere visible, but a fine hard glossy skin was coming up on all the wearing parts.

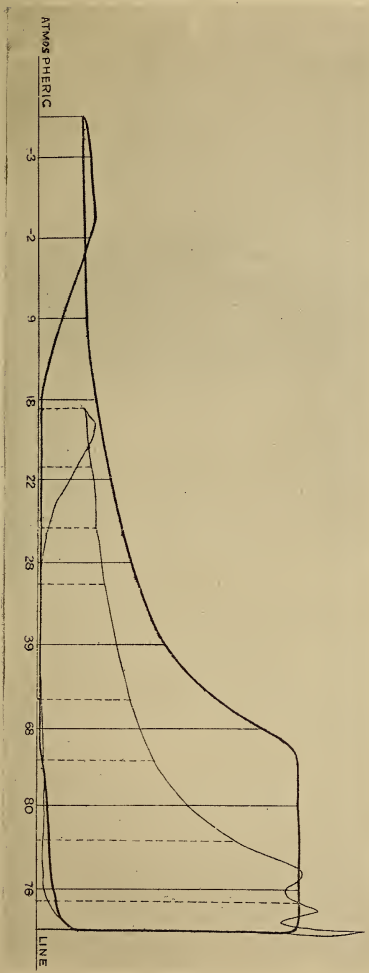
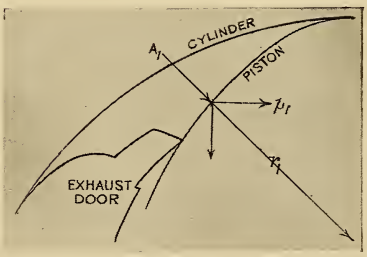


FIG. 12.—INDICATOR-CARD TAKEN AT 200 REVOLUTIONS PER MINUTE.

From the right-hand side of Brown's rotary engine shown by thin line. Thick line shows corrected diagram expanded from diagrams taken by Professor Jamieson, on June 4, 1891. Scale, 1·48 = 1 lb. pressure. Mean pressure = 33.5 lbs. per square inch.

From the general view of the engine it will be seen that I employed the rope-brake, but substituted the lower Salter's balance-spring for the dead weight hitherto used by engineers. I first introduced this modification of the rope-brake on March 29, 1889, when testing the Ajax gas engine, and it effectually minimizes the hunting action of the brake, enabling the observations to be taken with greater certainty. It also prevents the danger (which was inherent in the former method) of the lower weight being carried round by the fly should the ropes grip the same at any time. This form of brake deserves to be better known than it seems to be; for with it no lubrication whatever is required, and continuous runs of any desired length of time may be carried out without any fear from overheating or requiring to stop for adjustment. It



simply consists of an endless rope passed round the fly-wheel or brake-pulley, with combined wooden distance pieces and guards so as to keep it evenly adjusted, and two Salter's spring-balances. To find the net brake-load, you have simply to add the weight of the hanging part of the lower balance to its own net reading, and subtract from this sum the back-pull as registered by the net reading of the upper balance.

Since this was the first time that I had attempted to take indicator diagrams of a rotary engine, and never having heard of such having been taken before, I was slightly puzzled as to how best to obtain the motion for the indicator-drum so that it might move synchronously with that of the revolving piston. At last an eccentric was keyed

to the valve-gear end of the engine, so that its center line was fair in a line with that of the radial center line of the piston. The indicator-pipes were attached to the cylinder-cover at points

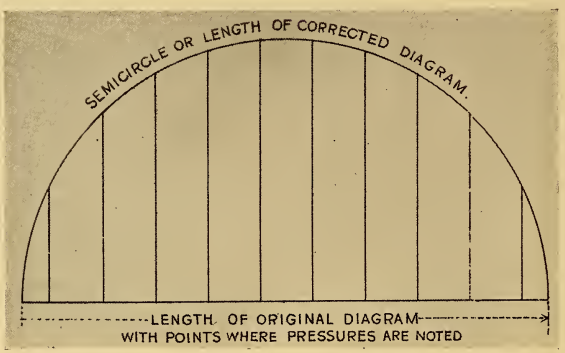


FIG. 10.

just beyond the noses of the exhaust-valve doors, in order that the indicator might truthfully register the variation of pressure from beginning to end of the strokes. I then took a number of preliminary diagrams, until I got uniform diagrams from each half of the piston's revolution. Since taking these diagrams it has been pointed out to me that although the center line of the eccentric and the center line of the piston kept time, the indicator-cord was moved in a straight line whilst the piston and eccentric were moving in a circle. Consequently, I have had to get the original diagram correspondingly corrected. The length of an original diagram, taken on June 4, has been considered as the diameter of a circle, and from the ten points of division, ordinates have been drawn (as shown by Fig. 10). The length of the semicircle and the intersection of ordinates therewith are evidently the true points of observation for the various pressures.

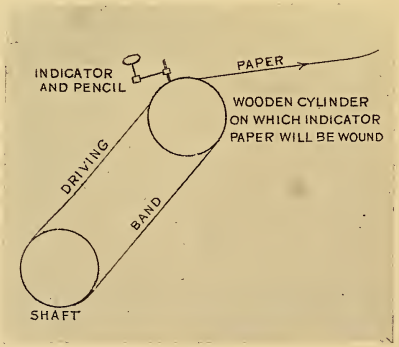


FIG. 13.

Further, the mean effective piston area and effective stroke of this engine are not easily ascertained; for the effective area on which the steam acts, as well as the effective moment of the force derived therefrom, are continually changing throughout the stroke or revolution of the piston. What I have done, therefore, in order to ascertain the indicated horse power, is this: I have found the effective area of the piston on which the steam presses at each of the ten points at which the pressures are marked on the indicator diagram, and thus calculated the work done for each tenth of half a revolution. The sum of these 10 valves gives the work throughout one stroke, to which was added the work done through exhaust-doors.

I may, however, remark that improvements in the distribution of the steam, the points of "cut-off" release, back-pressure, negative work, and compression, can only be studied by carefully taking and reading the true indicator diagrams of this engine. In order to obtain more exact diagrams in future, Mr. Paul has proposed winding a long sheet of indicator-paper on the central shaft and acting thereon directly by the indicator-pencil. I would, however, suggest the driving of a wooden drum at exactly the same rate as the shaft, in the manner indicated by Fig. 13. On this drum would be wound a continuous length of indicator-paper, and of acting thereon directly by the indicator-pencil, so as to obtain a perfectly continuous and synchronous representation of the variation of pressures taking place within the cylinders during each half of a revolution in the case of the double-door engine, and of course during a complete revolution in the case of the single-door one. The points claimed by Mr. Brown for his engine over those of preceding inventions of rotary engines are: Packing strips that are expected to wear uniformly and last a long time without requiring adjustment or renewal. Early cut-off with corresponding economy, due to taking full advantage of the natural expansive property of steam. A minimum of clearance space. Jacketing. A thoroughly well-balanced strong engine, occupying a minimum of space for the power developed, freedom from undue vibration and noise, combined with high speed and an economy of steam that has not been reached by any other rotary engine or even by any single reciprocating engine of the non-condensing and non-compound type. The possibility of compounding his engine, or even of adopting triple or further multiple expansion, and of using the highest practicable pressures.

A PHENOMENON IN THE FUSION OF MILD STEEL.*

By F. J. R. Carulla.

THE discrepancies in regard to the melting-points of certain iron and aluminium alloys, as stated by different observers,—a matter to which forcible reference was made by Mr. Hadfield in his paper on aluminium steel, which appeared in the second volume of last year's Transactions of this Institute,—has induced the writer to bring to your notice a circumstance which, whilst he does not profess to say it explains the variations referred to, may yet have some bearing upon them, and is otherwise of interest to iron and steel users and manufacturers.

The phenomenon in question is the remarkable one that the interior of a piece of mild steel may be raised to the fusing-point whilst the outside remains in the solid state, just as if one were to try to melt an iron tube, closed up at each end, and filled with some metal of a lower melting-point than iron, in which case the heat would penetrate through the iron and liquefy the interior long before the tube itself would be affected, and if there should happen to be some outlet or weak place in the tube, it might be left completely empty. Bessemer steel

*Paper read before the Iron and Steel Institute, London, on October 7.

makers, especially those who may have employed the system of upward casting, will be reminded of the shells of ingots accidentally obtained in the melting-shop by an incautious act, produced, however, by a different process, viz : by the cooling of the outside whilst the interior of the ingot remains in a molten state.

Shells have also been obtained by altering the nature of the exterior of a piece of cast-iron, so as to leave the interior more fusible than the outside. Henry Horne, so long ago as the year 1773, in his "Essays Concerning Iron and Steel," after describing Reaumur's method of softening cast-iron by means of a mixture of calcined bones and powdered charcoal, goes on to say :

"I have myself tried the truth of the hypothesis in a rough way, as far as nealing, or merely reducing, has any concern in the matter, by a great number of experiments, two only of which I judge necessary to recite by way of specimen. I had several small ingots of cast-iron, about ¾ inch thick ; these I put into a crucible covered all round with the matter above described, and in that situation committed them to the fire, where I suffered them to remain a sufficient time, then took them out, and gave them a strong heat, when the exterior parts were become capable of bearing even a welding heat, while the interior suffered an easy dissolution, and ran out into the fire. I ran some other ingots in the form of pistol barrels, which having treated in the same manner, the same consequence ensued ; the exterior cases, as before, remained firm and stable, while the interior dissolved and ran out, and left cases in the entire form of pistol barrels."

The instance, however, to which this paper refers, is altogether different from those just mentioned, and it will be perhaps best to give an account as accurately as can now be remembered of the circumstances under which the observation was made. Some years ago the writer was engaged at Sheffield in the operation of melting, in pots or crucibles, steel intended for the manufacture of wire ropes, the material charged being mainly Bessemer scrap of varying carbon contents, which, however, by the process became averaged, and the resulting product attained a uniformity that was much appreciated for the purpose named. It happened on one occasion that a crucible gave way in the furnace just as fusion was nearly complete, the greater part of its contents running out into the fire. The melter happened at that moment to bring the crucible out, and what he supposed to be an empty pot was found to contain a number of shells, having the shape of the pieces of steel originally charged, and showing that the interior of these had undergone fusion, while the outside envelope remained solid—a fact leading to the conclusion that the melting-point of the interior mass was lower than that of the exterior coating.

Two of the pieces found in that crucible are now shown. The larger piece, about 3½ inches by 1⅝ inches square, must originally have weighed about 41 ounces. It is now a shell of 14½ ounces. The smaller piece, about 3 inches by 2¼ inches, by ⅞ inch, will originally have weighed approximately 21¼ ounces ; its shell now only weighs 8¾ ounces. From these figures it will be seen that the larger piece lost by fusion of its interior about 26½ ounces, or 64½ per cent. of the whole ; whilst the smaller piece lost 17½ ounces, or 66½ per cent. of the whole in the same manner—two results that agree in a remarkable way. It would therefore appear from so close a coincidence as if mild steel of the dimensions given, having a sectional area of from 2 to 2½ square inches, possessed a coating of skin of about one-third of the whole mass with a higher melting-point than the remaining two-thirds forming the interior.

How far such a fact may have affected the observations on the melting-points of steel and aluminium alloys referred to at the commencement of this paper it is impossible to say, but it will be perceived that if the same heterogeneity occurred in their case as that which has been described, discrepancies in a number of observations are easy to account for. It is to be regretted that the composition of the steel as it originally went into the crucible is unknown. Scrap was being melted, much of which would be from cut-up rail-ends, but the square

piece looks like a portion of a billet which might have been of milder steel. At any rate, both shells now only contain a mere trace of carbon, the amount not reaching to 0.1 per cent., so that their resistance to fusion can be easily understood.

The phenomenon referred to is, however, interesting in other ways besides in its relation to the subject of melting-points. Some such result might, for instance, be expected from the facts communicated to this institute in 1881 by Mr. Stubbs, and subsequently corroborated by Mr. Snelus, that carbon, sulphur, and silicon become concentrated in those portions of the ingot that remain fluid the longest. This, of course, is the interior, so that from the very commencement the outside of the ingot acquires a skin of less fusible nature than that of its internal mass. In a more or less marked degree this liquation of the elements may be expected to occur in all steel that has been cast into ingot molds, for the same cause is likely to operate in every case, whatever the composition of the steel may be. Of course, subsequent treatment at the mill and forge, by subjecting the outside of the material to the oxidizing action of the air, will intensify the characteristics that make the outside of the ingot less fusible than the interior, but that the skin, even in the hardest steel, is of a different nature and tougher than the interior, is a fact that will be confirmed by those who are in the habit of handling tool steel, which by nicking or just cutting through this skin, may be easily broken, when often the bars bend if struck without such preparation.

What has been explained also brings into prominence the fact that, by turning and planing rolled or forged pieces of machinery, these are weakened in a disproportionate degree as the most valuable part of the piece is removed. It is obviously advantageous that where a steel forging can be finished under the hammer this should be done. Doubtless finishing by means of molds, so as to bring the article as near to the ultimate shape required as possible, is the best course to pursue. The hydraulic press will no doubt play an important part in this direction at no distant date, though much has already been done by working in this manner under the steam hammer. The writer, for example, remembers the manufacture of large screws for holding armor-plates to the sides of vessels, being carried on many years ago at the Atlas Works, Sheffield. These screws, whose thread was forged under molds, had the original skin of the bar left all over them, the forgings being further protected by galvanizing.

It is not forgotten by the writer that engineers advocate machining not only so as to obtain the symmetry that is so desirable, especially in pieces to which motion is imparted, but also so as to make visible any hidden flaws that might be present in a forging. The importance of this objection is not to be minimized, but apart from the fact that a forging with the tough skin on and some hidden flaw left might be preferable to one from which the skin has been removed, and the flaw "doctored up," it may be pointed out that in many cases simple polishing, say, for example, by means of the emery wheel, might effect the desired object without in any material degree weakening the strength of the surface protection. It can be imagined, at sight of these comparatively infusible envelopes, that it would be quite practicable to weld mild steel and obtain a fibrous product by piling and passing the heated mass through the rolls or working it under the hammer. Nevertheless, according to Mr. Skelton, some difficulty appears to have been encountered in the attempt to make rivet-bars in this manner from mild steel-plate cuttings, possibly not because of any inherent fault in the method, but because it may not have been carried out properly. as, for example, by the introduction of hard pieces in the piles.

On the other hand, Mr. Ratliffe, of the Mersey Forge, it will be remembered, read a paper before this institute in 1879, wherein he explained how he actually preferred to roll down his ingots of mild steel into bars, which he afterward piled to make into forgings. Not only did Mr. Ratliffe say that he obtained by that means a fibrous material, free from all crystallization, but also that he accomplished this desirable result at considerably less cost than by making

the forgings from large ingots. It is not likely that this economy would follow in every case, but much would be gained if the results obtained by the process were to induce confidence, and justify its adoption in cases of awkward forgings, which could be more easily formed by building up from bars than by hammering down from a large mass.

In conclusion, it may be pointed out how the characteristic to which this paper refers—namely, the greater fusibility of the interior of a mild steel bar as compared with its exterior portion—will assist operations in the manufacture of the Mannesmann tubes. Without asserting that the phenomenon in question plays an important part in the process, it is certainly interesting to note that, as the interior of the bar must be in a more pasty condition than the outside, being nearer its melting-point, the circumstance, if not actually conducive to the production of a hollow center, will at any rate offer little opposition to the forces that induce its formation.

COAL AND ORES IN WYOMING.

THE future has much in store for some of the great Western States if the advantages they possess are improved. Everyone who hears anything of Wyoming associates the State with the raising of cattle, and very few are there who know of its immense deposits of coal and iron ores as well as some of the precious metals. Mr. Charles A. White, who for some years represented the *Illustrated London News* as the manager of the American edition, has recently removed to Cheyenne, Wyo., where he has extensive interests in coal and iron lands. In a recent interview with him he said that there is every reason to believe that the citizens of that State are now beginning to realize the great wealth that lies buried around them. Since 1868, when but 6925 tons of coal were mined, the output has wonderfully increased, and in 1889 there were nearly 1,500,000 tons mined. Some of the coal is not good, but a large part is free from slate bands and does not slack, which is one of the faults much Western coal possesses. While the coal is perhaps not equal to much of the coal in Pennsylvania, the iron is remarkably good, and from the mines are obtained some of the best Bessemer ores. The percentage of sulphur and phosphorus is very small, and an analysis by Professor L. D. Ricketts shows that none of the iron in the Hartsville district contains sulphur, and but a few contain phosphorus, and then but a trace.

G. M. Davidson, the Chicago chemist, recently wrote a resident of Cheyenne:

"In order to give you a comparative idea of the value of these ores, I add the results of analyses of several well-known Lake Superior ores, which are accounted the best to be found along our line. These analyses I made several years ago in the laboratory of the Cambria Iron Company, the samples in each case representing shipments of the ore as received at the furnaces. The samples you sent me I have called Sunrise ore. I consider it one of the best Bessemer ores to be found in this country. It is not only high in iron, but very low in phosphorus, and in my opinion would make an excellent grade of pig-iron suitable for making a high-grade of Bessemer or open-hearth steel."

Name of ore.	Metallic iron.	Phosphorus.	Sulphur.
Hartville or Sunrise	68.10	0 058	2.46
Quinnafac	57.94	0.053	7.69
Norway	52.10	0.030	12.29
Chapin	65.12	0.072	6.25
Vulcan	61.34	0.118	5.82
Cyclops	60.54	0.038	8.20
Michigamnic	57.38	0.096	7.50
Marquette	58.60	0.052	4.81

"You see," added Mr. White, "that these figures are very interesting, for they show that the famous ores of Lake Superior do not excel those of our State, and as we possess plenty of coal, all that is needed is a little enterprise, and Wyoming may soon take her place as a great ore-producing State."

THE AMERICAN BAND-SAW MILL.

By Henry Harrison Suplee, M.E.

THE claim of America to the development of the band-saw mill is one which can hardly be contested, but at the same time England and France have both had their share in its origin and advancement. To England the original invention of the band-saw machine is undoubtedly due, and the machine which was invented and patented by William Newberry, of London, in 1808 (Fig. 1), is without doubt the first organized and operative machine of the kind ever made. The singularly complete construction of this early machine renders it a matter of surprise that it failed to come into immediate use, and the only explanation which can be offered is that of the difficulty, or rather impossibility, of procuring suitable blades at that early date.

As a consequence of this shortcoming, the machine remained for many years unused; a forcible example of the manner in which one idea may come into the world far too soon to be of immediate service, and so be compelled to wait until some sister art has caught up to it. In this case the invention of Newberry had to wait for over forty years before the advancement in the art of saw-making reached a point where practical and satisfactory blades could be made. It was at this stage that M. Perin, of Paris, succeeded in making blades which when used upon machines also built by him were practically successful. The machines and blades made by M. Perin were exhibited at the Paris Exposition of 1867, at which time the Grand Cross of the Legion of Honor was conferred upon him as an acknowledgment of his labors.

Perin's machines were of small size and moderate capacity, and were intended for hand feed, being indeed the prototypes of the various and well-known forms of small band-saw machines which were introduced into this country about 1870, and which have since been so improved and modified as to be in every way far superior to the French designs. The efforts of another French engineer, M. Arbey, were, however, directed toward the adaptation of the band-saw for cutting larger lumber, and the mill shown in Fig. 2 is a form made by him in 1873. This machine possesses all the essentials of a successful mill, but at the same time is so evidently modeled after the small hand-machines then in use as to be unequal to work anything but moderate-sized work. The uncertainty which at that time obtained in France appears by the following quotation from Arbey's catalogue of 1873, in which the experimental condition of the band-saw mill is well shown. After referring to the vertical reciprocating frame saw, and the band-saw, M. Arbey proceeds as follows:

"It is well to observe that the reciprocating vertical saw-frame is better adapted for straight cutting than the band-saw, for any ordinary workman can easily work the former, whereas the latter requires an intelligent man.

"This will easily be understood when we state that a band-saw requires careful sharpening, is generally from 24 to 30 feet long, and cannot be strained too tightly for fear of heating the bearings. If the wood is at all bad to work, the saw easily gets out of the straight line and the best guides in the world cannot set it right again.

"The ease of sharpening the saw in a vertical frame and the facility of keeping it rigid, besides many other recognized advantages, give, therefore, to the vertical saw-frame a great superiority over the band-sawing machine for sawing in a straight line."

These objections and difficulties, so naively stated in the manufacturer's own catalogue, most certainly existed in the machine as then built, and it remained for American engineers to take up the problem and solve it by redesigning the entire machine, instead of quietly recommending the user to adopt some other form. Indeed, at the very time

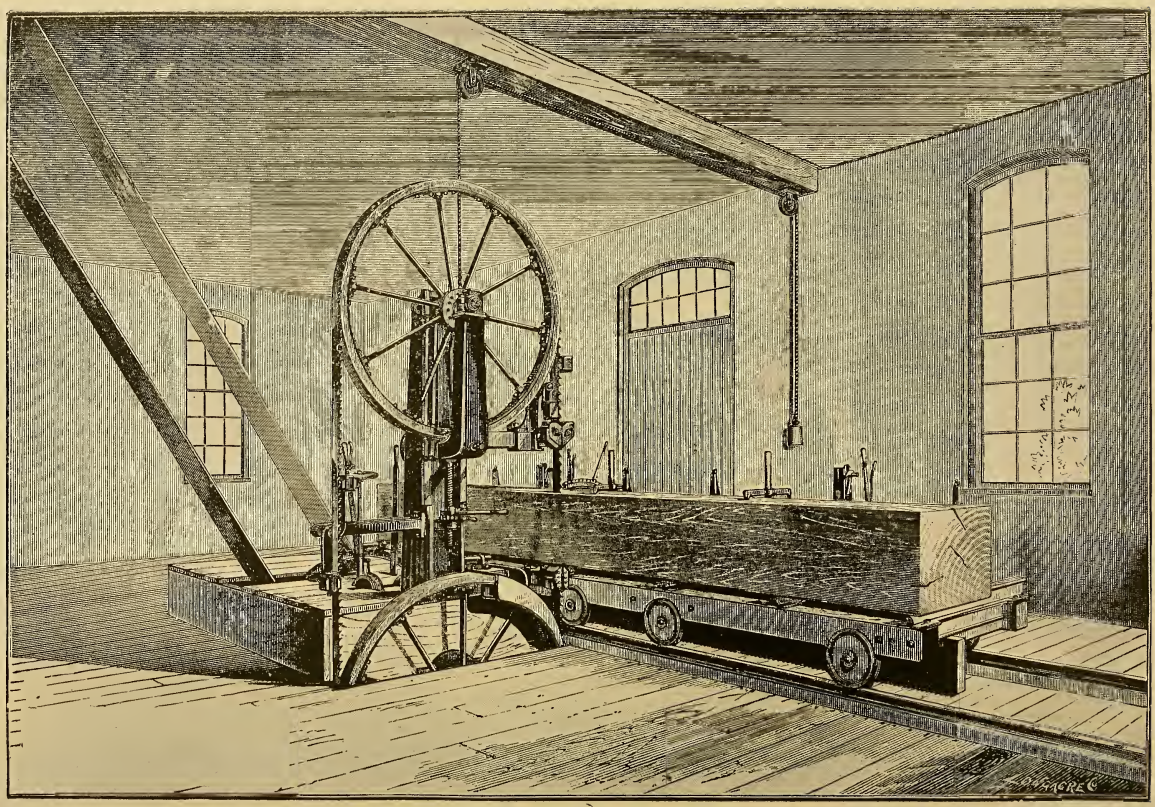


FIG. 4.—THE BAND-SAW MILL AS PERFECTED IN 1874.

when the above quotation was published, band-saw mills were running with good success in America, and the modern machine is so thoroughly American in its design and construction as fully to warrant the title here given.

The early American mills were rather primitive in appearance, but they were constructed with a full appreciation of the fact that a band-saw mill for sawing logs must be constructed upon a different plan from a small machine for cutting light stuff. One of the first mills in America was built early in 1870, and erected in the mills of Mr. J. J. Van Pelt, of New York, by Richards, London & Kelley, of Philadelphia. In this mill the wheels upon which the saw-blade was carried were supported upon a heavy wooden post, framed into the timbers of the building in order to assist the heavy tension upon the blade, the stress being as high as 4 tons and the length of blade 55 feet. This form of construction met the difficulty of hot bearings, mentioned by M. Arbey, simply by putting the material in the line of the stress, and thus avoiding the springing of the frame and inevitable heating of bearings which follows such springing. The fact that the bearings could stand this strain revealed another weak point, which the lighter French machines had not been obliged to meet. This was the weakness of the wheels, as then made. The wheels of the French machine, and of some of the early American ones also, were made of cast-

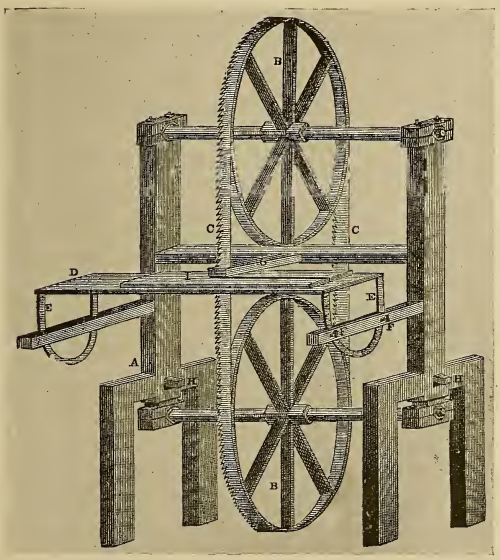


FIG. I.

iron, and the same material was used for the large wheels, 6 feet in diameter, of this mill. These proved unequal to the stress due to the tension of the saw, being literally crushed, and hence originated the wrought-iron wheels, which indeed made the success of the modern mill possible.

Another early mill, also built in 1870, by J. R. Hoffman & Co., of Fort Wayne, Ind., is shown in Fig. 3. This mill is very primitive in appearance, but was put

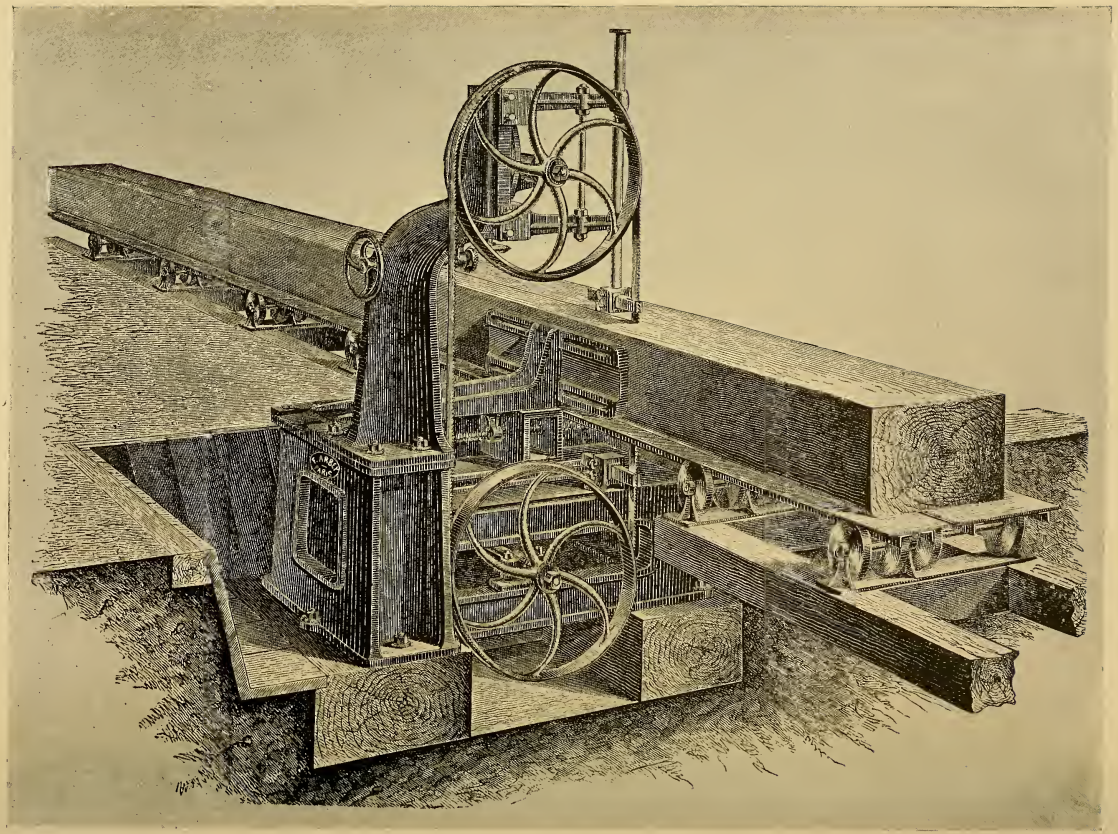


FIG. 2.—BAND-SAW MILL, DESIGNED BY M. ARBEY IN 1873.

into successful operation, and following these pioneers various other mills were constructed. It was soon found, however, that something still more substantial must be produced if the service of the American saw-mill was to be done by the band-saw. The various points which M. Arbey offered as objections to the band-mill existed to a much greater degree in American practice, as the logs were much heavier and far greater capacity was demanded.

The chief claim of the band-mill was the great saving of lumber over the wasteful circular-mill, the thin blade taking not more than $\frac{1}{12}$ of an inch kerf, and greater weight and stiffness to the parts made it much easier to keep the saw in the straight line of the cut.

By 1875 the mill had reached the form shown in Fig. 4, and had really become a practical and serviceable machine, although as yet it was only used for the more valuable woods, in which the economy of their blades was most apparent.

In order to appreciate the character of the problem which the designer of a heavy band-saw mill is called upon to solve, the conditions under which the machine must operate should be examined. An endless blade of steel, say

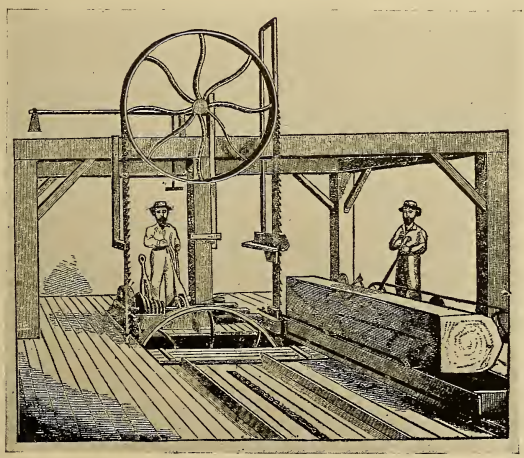


FIG. 3.—BAND-SAW MILL IN 1870.

while the circular-saw required from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch. The great capacity of the circular-mill, however, has always made it a favorite, and when the band-mill could only cut 8000 to 10,000 feet per day against 40,000 to 80,000 for the circular-mill, it was evident that capacity was the next point to be met by the band-mill. Increased capacity meant increased size, high speeds, and greater stiffness, all of which came in due course. The wooden post was superseded by the iron column, and the speed of saw-blade from 5000 to 6000 feet per minute, while improved guides

eight inches wide, fifty feet long, and one-sixteenth of an inch thick, is to be strained over a pair of wheels to a tension of 10,000 pounds per square inch, and then driven at a velocity of a mile and a half a minute. Meanwhile a log, ranging from three to six feet in diameter, is to be hurled against one end of this steel belt at the rate of 200 lineal feet per minute, and then jerked back at the rate of 600 feet. During this ordeal the saw-blade must not vibrate or waver, as every vibration is at once recorded upon the surface of the board ; it must not lose speed on entering the cut, nor

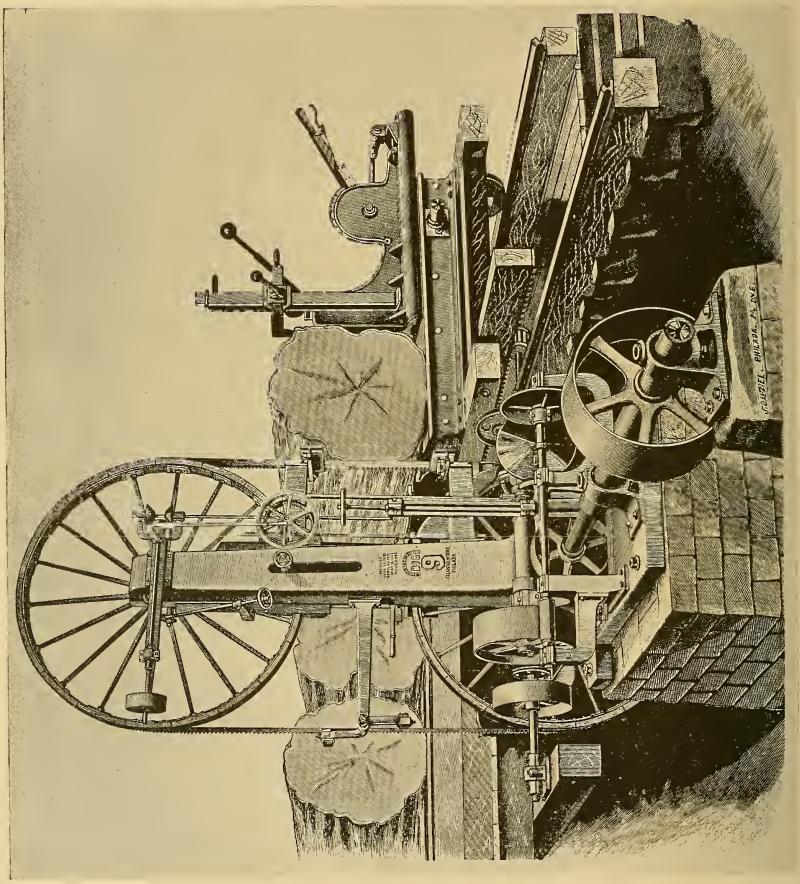


FIG. 5.—THE MODERN BAND-SAW MILL.

gain speed on leaving it, neither must it change its position on the wheels. The shocks of loading and handling must be met and all the varied adjustments and movements must be fully under the control of one man. This state of affairs must be maintained without heating, breakage, or delay, for ten hours continuously every day for six months at a time, before the machine can be called a success. All this has been done successfully and the modern American band-saw mill is to-day running in the white pine country of Michigan and Wisconsin, in the poplar of the South, and the fir and spruce of the Northwest side by side with its old competitor, the circular-mill, doing equal duty and turning out twenty per cent. more lumber from the same quantity of logs.

The modern mill is well shown in Fig. 5. All the essentials of the Newberry machine of 1808 are there and it is only in details and design that the machine is modified. The heavy iron column effectually resists the tension of the saw and the massive sole plate and heavy foundation aid in resisting shocks. The wheels, of steel, wood, and rubber, are strong, steady, and adjustable. The upper wheel, which is driven only by the saw-blade, is made as light as possible consistent with strength, while the lower wheel is purposely made heavy, in order to act as a fly-wheel and prevent retardation and consequent breakage of saws on entering the log. The upper wheel is also hung upon its saddle in such a manner that it can be adjusted in three planes, so that until the fourth dimension in space is discovered it can meet all requirements as to position. The saw-blade is truly guided in the line of the cut during the forward movement of the log and retracted so as to give clearance during the rapid return travel of the carriage, and the numerous adjustments are all controlled by the various band-wheels at the back of the column, so that the operator, whose position is on a platform constructed over the feed-works, can control everything at will.

A mill of this kind, with saws in good order, can cut from 60,000 to 70,000 feet of inch boards in ten hours, and the economy which results from a kerf of $\frac{1}{12}$ of an inch as compared with the kerf of $\frac{3}{16}$ of an inch made by a circular-saw can readily be calculated.

The care of the blades was formerly a great bugbear to many who were otherwise favorably inclined toward the band-mill. The blades for the early machines were imported from Paris, but the interruption which occurred in 1870–71, during the siege of Paris, led to the development of the industry in America, and American blades are now used in all large mills. The designing of proper machines and tools for sharpening, upsetting, and swaging the teeth has also greatly facilitated the introduction of mills and now but little difficulty is found in the care of blades.

The whole development of the American band-saw mill is an excellent example of the expansion which attends the introduction of machines or devices in use in Europe into the Western world. That such an expansion should result is but a natural consequence of the environment, for the demands which are made are imperative and the reward for meeting them ample. The future of the band-mill is only limited by the demands, and the probability of a mill of capacity to cut the giant redwood-trees of California may be inferred when it is known that the demand exists and that, on paper at least, the American engineer has been at work.

BLACKSMITHS ARE SKILLED WORKMEN.

THE *American Machinist* comments on the remarks of a contemporary which seems to have made the discovery that "there is a prevailing idea that a blacksmith is anything but a skilled workman," and on this supposed discovery proceeds seriously to prove, as though it were a matter actually needing proof, that the blacksmith is really a skilled artisan. This is simply an effort to prove what no one, so far as we are aware, has ever thought of denying, blacksmiths having been regarded from the earliest days of metal-working as being among the most skillful of mechanics.

A BLAST FURNACE BLOWING ENGINE.

ON the following pages are shown several illustrations and drawings of a blast furnace blowing engine, which Mr. Fred. W. Gordon, M.E., in a paper read before the American Society of Mechanical Engineers, stated was a result of an effort to design a standard form for such machinery. The engine illustrated was built by the Philadelphia Engineering Works, of Philadelphia, Pa., for a blast furnace located at Birmingham, Ala., where it is now in operation.

The blowing cylinder is 84 inches in diameter, the steam-cylinder 42 inches in diameter, and the stroke 60 inches. Some years ago blowing engines were ordinarily made with a stroke of 7 feet, and subsequently were made with a remarkably short stroke. It seems that the public demand for things brings about an averaging of mechanics' notions, and for good-sized engines the favorite stroke is now 60 inches. The bed-plate is box form, 13 feet long, 6 feet 3 inches wide, and 2 feet 3 inches deep, the metal entirely surrounding the rectangular section, excepting the opening for the removal of the cores. The two cross girders forming the ends of the bed-plate, and the side as far as the bosses for the steam-cylinder, are 14 inches wide. Besides the cross and box girders there are two ribbed plate cross girders, which stiffen the entire frame at a point where the steam-cylinder is bolted to the bed-plate. The bottom of the bed-plate is flat, to facilitate the bedding and to secure strength in the masonry. There are eight foundation bolts, each 2 inches in the body, with 2½-inch threads, passing through this bed-plate and through the anchor plates which extend entirely across the foundation.

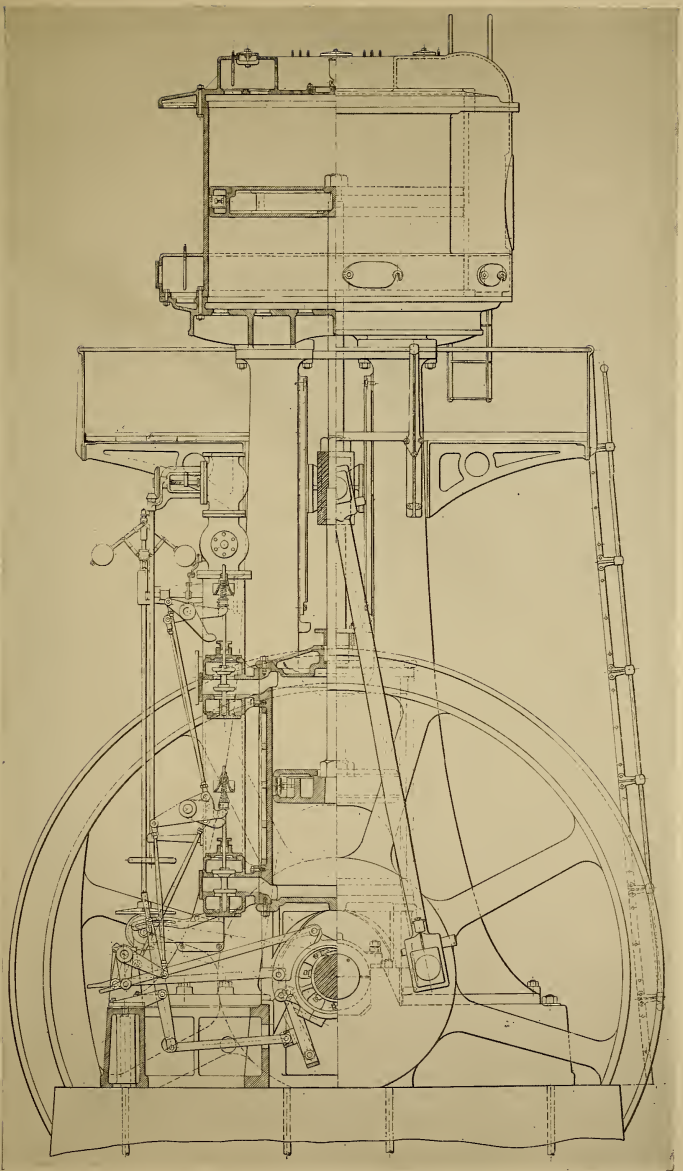
The bearing for the main shaft is made of cast-iron, babbitted, planed in and scraped upon the bed-plate. The seat of this bearing is well up, leaving the box-frame under each bearing to receive weight of the fly-wheels and the thrust of the steam when they both come together at the bottom center, 24 inches deep and 22 inches wide, having 3½ inches metal on top and 2 inches on each side and bottom.

There are two housings or frames. They are hollow box castings of rectangular section. The section of each of the four legs is 22½ x 11 inches at the bottom, and 16 x 11 inches at the top. They are bolted directly on top of the bed-plate, and on top of them is bolted the lower head of the blowing cylinder, and they in turn bolted to the steam-cylinder near the top head, to give ample rigidity to the whole structure, while allowance is made for the expansion and contraction of the cylinder.

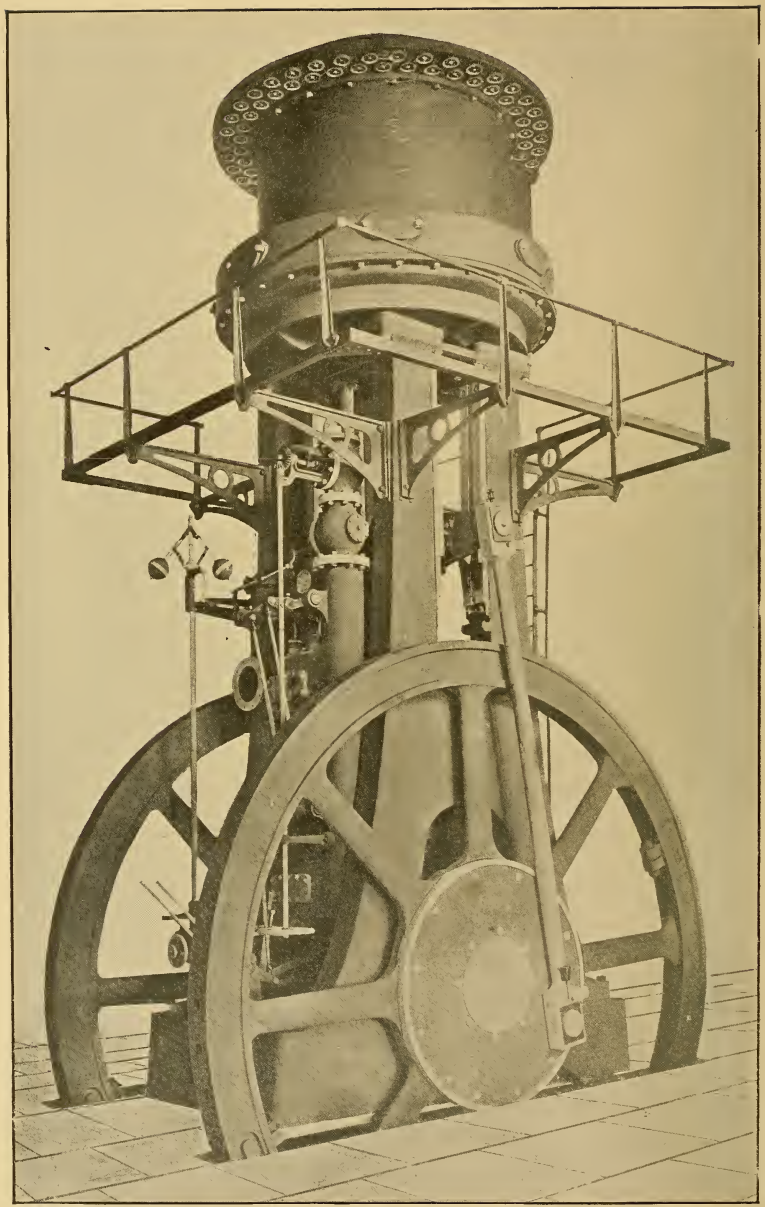
There are two fly-wheels, each 18 feet in diameter, weighing 15 tons. They are made in two sections, planed at the joint and on one side of the center flange, after which they are carefully fitted and bolted with taper bolts to the crank-plate. The crank-plates are then forced upon the shaft and thoroughly keyed to it to remain there. The crank-pin holes are then bored out by using the main shaft to carry the bearings of the boring-bar, whereby accuracy in alignment and distance is secured. This is considered highly important in this type of engine, as in crossing the centers the slightest variation in the positions of the crank-pins will strain the whole engine. Rocking cross-heads do not relieve these strains, though they mitigate them, while with true work and occasional trammeling of the connecting-rods they never exist.

The main shaft is of wrought iron 15 inches in diameter, with bearings 24 inches long. The shaft is turned parallel, except a very slight reduction where the crank centers are forced on.

The lower head of the steam-cylinder has four legs strongly ribbed to its whole surface. The bed-plate has four pads or bases corresponding to those, and the lower cylinder-head is placed upon these and accurately adjusted in position, and is bolted to the bed-plate by four 3-inch steel bolts, passing well into the bed-plate and keyed to it. Upon this lower head the cylinder is bolted in the



BLAST FURNACE BLOWING ENGINE.



A MODERN BLOWING ENGINE. BUILT BY THE PHILADELPHIA ENGINEERING WORKS, PHILADELPHIA, PA.

usual way. The distance between the housings is just sufficient to admit the cylinder, and its width, added to the width of the two housings, is the width of the bed-plate. In other words, the housings are as close together as they can possibly be to permit the withdrawal of the steam-cylinder. The length of the cross-head and shaft is reduced to a minimum, and the crank-pins are brought as close as practicable to the fly-wheels. The crank-pins are steel, 7 inches in diameter, and being accurately bored, as referred to, never heat with ordinary attention.

The steam- and exhaust-valves are the ordinary double-balanced poppet-valves. The steam-valves are made in one piece, the lower one being made small enough to drop through the seat of the upper one. They are 7½ and 7 inches in diameter area, 83 square inches or 6 per cent. of the area of the cylinder. This want of balance is to furnish a water relief through the steam-pipe, as in the lifting of an ordinary slide-valve. The exhaust-valves have the lower valve the larger, which is introduced as a ring, the lower guide-stem being cast with the upper valve. The valve and seats are

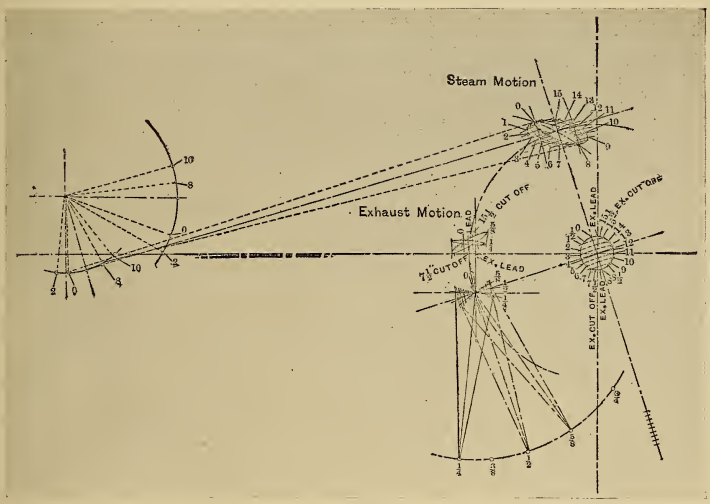


FIG. 2.

The steam piston-rod is secured to the steam piston by a nut on top of the piston-head. This requires an enlargement of the rod at the lower end, the head to be passed over the rod and the nut following. The purpose of this is to get at the nut and screw it up properly, which is very difficult and is likely to be neglected when the nut is on the bottom of the piston, and should this large nut get loose on the bottom it may quickly run off, while if on the top it will work off very slowly and pound before any damage is done.

in all cases made of cast-iron, and seat at an angle of 60°. They are ground in with steam on the side-pipe. The side-pipes are each 12 inches in the clear, the exhaust and steam being both alike. All the valves are actuated by a single eccentric, illustrated in the accompanying drawing (2) and by the diagram (5).

The exhaust eccentric-rod is pivoted to the eccentric, almost directly in line from the center of the shaft to the pin of the rock-arm. This position secures practically invariable exhaust, there being no variation in the lead, and the

lift and compression varying but slightly. The steam connection is pivoted to the eccentric strap at right angles with its point of suspension, and in this position the most sensitive variations are obtained. By moving the hand-lever shown in the drawing, the steam follow can be instantly changed from $\frac{3}{16}$ of the stroke, or $11\frac{1}{4}$ inch follow, to $\frac{5}{8}$ of the stroke, or $37\frac{1}{2}$ inches follow, or between the expansion of 5 to 1 and 5 to 3. The action is entirely a rolling one upon pins, and is not liable to derangement of any kind, as there are no adjustments to make except when grinding the valves in. That required for wear of the main journal is effected by the screw supporting the small bracket, the only springs about the entire gear being upon the valves to cause them to close promptly. When the packing of the stems is

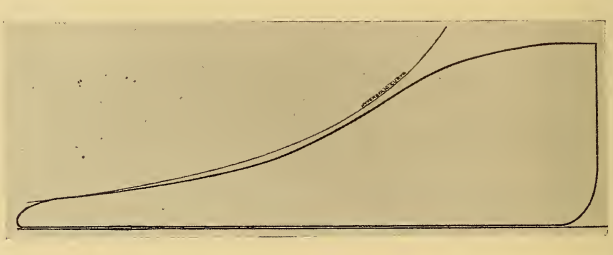


FIG. 5.

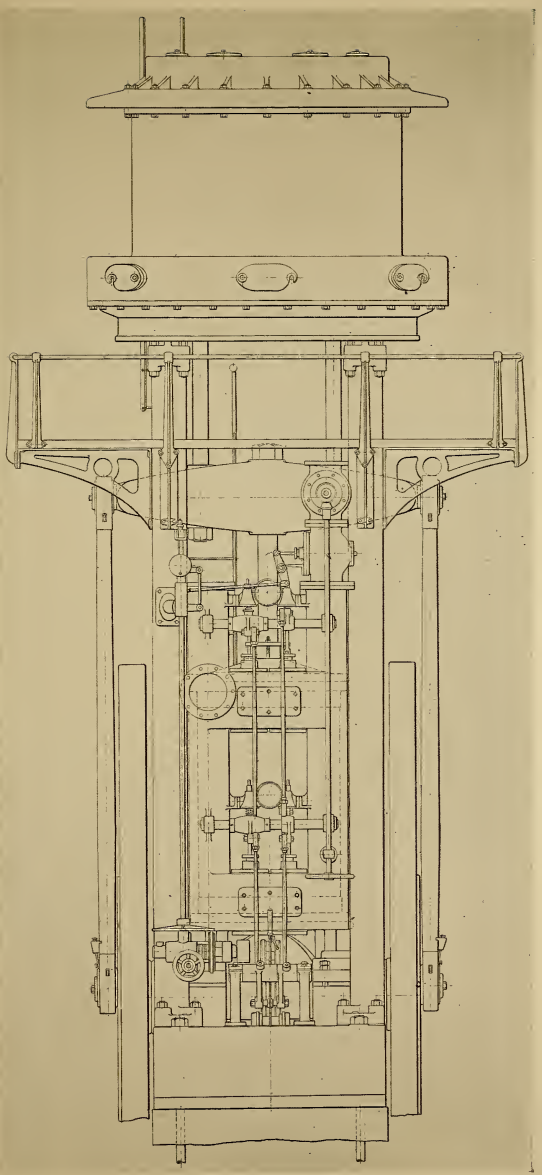
screwed down too tightly, by setting this gear to secure the shortest cut-off while there is still an excess of speed to the engine over that desired, the governor, as shown, will control it with very little wire-drawing, and good economy will be secured. The drawing (2) gives the impression that the clearance is large, yet it is but 3.4 per cent. figured on $\frac{5}{16}$ inches between the piston and cylinder-heads at dead center.

The cross-head is a wrought iron forging 24 inches deep in the center, the form being parabolic both above and below. The steam piston-rod passes through the center and is screwed up with a large nut on the top, the piston-rod being 6 inches in diameter. The blowing piston-rods pass through the bosses $20\frac{1}{2}$ inches deep and $9\frac{1}{2}$ inches in diameter. Each of these rods is $4\frac{3}{4}$ inches in diameter, all the rods being steel. A cross-head constructed in this manner requires very accurate boring. The three holes must not only be actually parallel, but they must be at right angles with the centers of the end pins. This is attained by the use of a horizontal milling and boring machine of the Niles Tool Works' manufacture. The cross-head being set to the machine, the three holes are bored without again moving it. We do not even depend on the accuracy of the machine in this case, as the cross-head is set accurately to the spindle of the machine. The shoulders for the piston-rods are brought exactly to the center of the cross-head.

The blast cylinder piston-head is operated by two rods, that the strain upon a very large head may be better distributed than by the use of the central rod, and to effect better connections with the cross-head.

The connecting-rods have solid ends, adjusted by keys, the brasses being very heavily backed with a wrought-iron pad. Each slipper is 10 inches wide and 16 inches long, or 320 square inches to receive the strain. The pads have no provision for setting out, as the wear is insignificant, and when it is necessary we propose to introduce a liner next the cross-head. This makes a more rigid adjustment than any screw arrangement, and has to be done so seldom that the trouble of doing it is not worth consideration.

The blowing piston-head packing-ring is brass, set out with springs with a long range of elasticity and light pressure. It is a single ring in segments accurately fitted together and turned true on top



PLAN VIEW.

and bottom and on the outside. The ring wears well and keeps tight, and requires no attention until a new one is needed. The follower bolts are screwed into brass nuts in the web of the spider, as difficulty has been experienced with nuts coming off.

The valves of the blowing cylinder (6) are so disposed that they all fall to their seats by gravity, requiring no springs, used only to avoid the slamming noise of the valve when opening. The valve gives a clear opening of 10.3 square inches, is $\frac{1}{16}$ inch thick, and weighs but 6½ oz., which is .04 pounds per square inch. The seat and guard are independent of the head, and together form the cage of the valve. Both are secured with a long bolt, adjusted from the outside, and are gotten at from the hand-

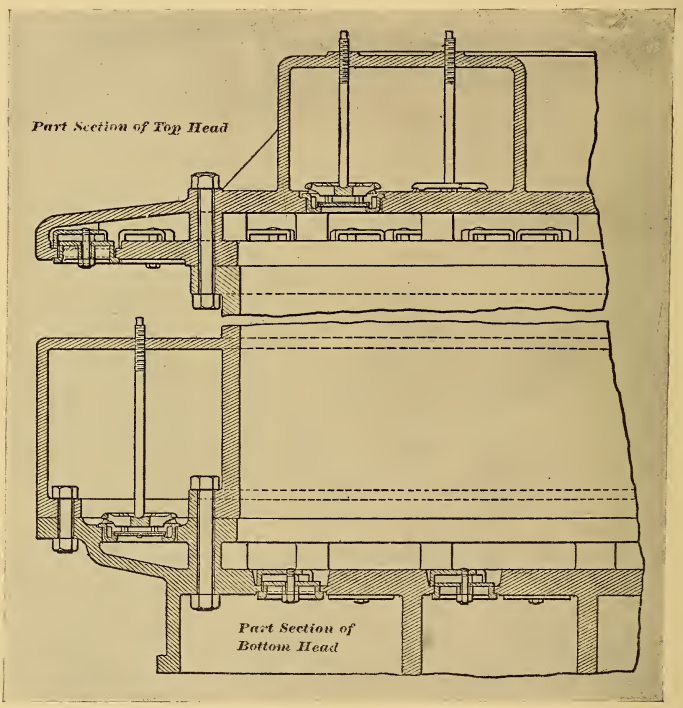


FIG. 6.

and are readily taken out and replaced in every instance without entering the cylinder, and in a moment's time. The construction is readily understood from the drawing. The outlet-valves are of steel with leather on the back (not on the face). The face of the valve is ground in the lathe where it seats, the seat being turned true to receive it. The leather is hole openings, placed conveniently around the outlet chambers. The surface of the cylinder receiving the cages is faced as is the cage where it rests upon the cylinder. A cage can then be introduced and made secure at once, without any jointings of gum or other packing being used.

The inlet-valve is of similar construc-

tion, as shown in the large drawing, but the valve is made of pure vulcanized rubber as good as the market affords; it is ⅜ inch thick and 4½ inches in diameter. The inlet-valve never comes in contact with a heated atmosphere, and this gum valve (being absolutely tight) does not become heated, and is very durable.

The outlet-valves are made of metal, as they are subjected under pressure to a high temperature which soon crisps leather and softens gum.

For quick-motioned engines anything in the form of springs to close or ease its opening, or anything in the shape of hinges, where the wearing surfaces cannot be properly lubricated, is thought objectionable. The valve described avoids the use of hinges and wearing surfaces and springs. If the valves are heavy, or the use of springs is necessary to close them quickly, or if stiff hinges are to be overcome, there will exist a serious impediment to the flow of the air. The best which can be said of a valve is that it is only an interference to the direction of the flow, and this would be the case if it were as light as the air itself—lifting without resistance. To the inefficiency of the opening (caused by its form and the change of direction of the currents, effected by the valve) must be added the weight of the valve or its resistance to opening, to get the total difference between the pressure inside the cylinder and the atmosphere for the speed at which the air is entering.

From this reasoning it is apparent that the more freely the valve will open the nearer it is to the requirements, provided it will close with sufficient promptness to prevent a loss by the return-stroke. We have found that there is no liability to loss in this, as the lightest valve prepares to seat itself as the engine approaches the center, and shuts instantly so far as the senses can appreciate it, the instant the center is reached.

These valves are made as large as it is thought to be advisable for great durability, and are made sufficiently numerous to give the requisite effective opening with a lift of but $\frac{9}{16}$ of an inch.

From the indicator diagram of the blast cylinder (Fig. 7), it will be seen that the inlet-valves show so little resistance to the in-going air that the lines on the card are not distinguishably separated. This was taken with a 10-pound spring, the pressure by gage being 4½ pounds, and the speed 35 revolutions, the stroke of the engine being 4 feet. The outlet-valves indicate a slight resistance, which cannot be measured, owing to the varying pressure in the outlet main.

Advocates of mechanically moved valves present three reasons for their use, all of which are theoretically very attractive. The first is the freedom from slamming, and consequently less repairs; the second, efficiency of opening, and consequently less waste of power; and the third, less dead space.



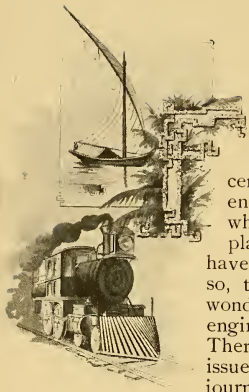
FIG. 7.

The efficiency of the opening of the valves is all that could be wished. The clearance will bear very favorable comparison with any class of construction, being but $2\frac{15}{100}$ per cent., including ⅜-inch clearance between the piston and the heads, which is rather more than is absolutely necessary; but, considering the character of the people into whose hands these engines sometimes go, it is not best to run them much closer. But leaving out this ⅜-inch clearance, the actual clearance due to the delivery or receiving chamber and valve-cages is but 1½ per cent.

The total weight of this engine is 100 tons. It is designed to blow 15 pounds pressure per square inch at 40 revolutions per minute, delivering 15,000 cubic feet of blast per minute piston measurement.

THE FUTURE OF STEAM.

By Fred. H. Colvin.



FOR some years so much has been said concerning the different forms of energy which are to supplant steam, if they have not already done so, that one is apt to wonder why the steam-engine still exists. There is scarcely an issue of an electrical journal that does not herald the victory of another conquest, while the advocates of compressed air, chemical and gas engines are likewise busily engaged in "relegating the steam-engine (and especially the locomotive) to the scrap heap."

But as the most casual observer must be convinced that the era of the steam-engine has not quite departed, judging from the examples on every side, it is not strange that one is tempted to inquire into the claims made by the advocates of the different systems, and determine what the facts show of their respective agents.

Compressed air, in its legitimate field, is a most useful agent for the transmission of power, but in most cases is dependent upon steam as the compressing agent. In rock-drills and other air-operated engines (and in some parts of England these air-engines form quite an extensive industry), train-brakes, molding machines, etc., its usefulness has hardly been questioned, though of late it has been rivaled in the rock-drilling field by the electrically-operated drill.

Judging from the extensive use of steam-drills in nearly all open cuts, quarries, etc., where the exhaust is not objectionable, steam used directly still seems to lead, which forms a basis for the opinion that it must be the most economical in this field.

In underground work, however, it must give way to the less objectionable methods, even if the cost of operation is considerably increased, while the exhaust from the air-operated drills must aid in the ventilation of the chamber, which is a very desirable feature.

The main objection to the use of air seems to be the annoyance caused by the formation of ice at the exhaust opening, which, however, can to a great extent be prevented by proper construction.

The suggestions of Mr. William L. Saunders, M.E., of New York, before the Franklin Institute, in a lecture before that body on December 11, 1891, seem to have much to recommend them. He proposed, and gave his own experience to show, that the efficiency may be greatly increased by retaining as much as possible the heat of compression, which will to a great degree prevent the formation of ice at the exhaust. He maintains that by retaining the heat of compression, by preventing radiation from the air-pipes as is done in steam-pipes, and by supplying by external means the loss in heat from the compressor to the motor, the compressed-air engines are placed upon a fair footing, but not otherwise.

In other words, much of the energy is wasted by cooling the compressors, which if retained, as in steam practice, would greatly increase the efficiency of the air-engine,—a proposition that seems very reasonable indeed.

In speaking of the "legitimate field" for air, the attempted application of it to impractical schemes seemed to warrant the term, "illegitimate field," though it cannot be said to fail through any fault of the air itself.

To those who have inspected the exhibition plant of the Pneumatic Railway Company of Philadelphia, the term will seem applicable. To those who have not, a few words in explanation may be of interest. This scheme is to use a tube or conduit in which a double-

headed piston travels, connected with the car above in a similar manner to the grip in the cable systems, reaching through a similar slot between the track. This slot is closed by metallic slides, one foot in length (six inches on the model railway), which are operated by the grip itself as it passes along. By exhausting the air from the front side of the piston and introducing compressed air in the rear if desired, any speed may be attained, 300 miles per hour not being considered impracticable, and it is claimed at such a small expenditure for power as to render it "the coming mode of locomotion"—on paper at least.

The system is claimed to be extremely "flexible," and one of the assertions of the inventor may be taken as a proof of this. "A loaded car running twenty miles an hour may be brought to a stand-still almost instantly by a person standing beside the track taking hold of the car, and this without injury to the person or occupants of the car." Can any more "flexible" system be devised?

The pneumatic tube system must not be confounded with this, for that is one of the useful means of transmission for small parcels at least, and its applications are extending in many directions. While there are many forms of energy that are to supplant the steam-engine in everything, the majority of them are content to take the transportation business and consign steam to the central station as a means of supplying them with their particular form of energy.

In this field the compressed-air systems have never played a very important part, although there is in Chester, England, a tramway which is said to be in successful operation. Each car carries its own supply of power, which can be renewed at various points on the route with little or no delay. Unless the cost is excessive, it seems to be admirably adapted for surface roads in cities, as it is not dangerous in the least (except the remote possibility of the air-tanks bursting), and emits no dangerous or obnoxious gases.

In the consideration of electricity as a form of energy, the utmost caution must be observed if fairness and justice are to govern the conclusions.

There has been much written *pro* and *con*, too much prejudice being incorporated on both sides of the question, and it is a difficult matter to get at the true facts without personal experience in that line of engineering.

The worst enemies a new idea or new machine can have is its too enthusiastic friends, and this has surely been and is yet to a great extent the case with the electrical fraternity, whose extreme friendliness has been a detriment to the cause by leading it into rash promises and statements that have not and cannot be fulfilled. When a statement is made to the effect that a 5 H.P. electric motor has been installed to do the work of a 15 H.P. engine, or that it is doing more work than a 10 H.P. engine, there is a decided discrepancy somewhere.

As if a horse power of electrical energy was more powerful than a horse power of any other form, it would be laughable were it not so serious a question, for anything that tends to cause lack of harmony or distrust between the different branches of engineering is to be deplored. And yet when such statements are continually being made the cool-headed engineers of other branches cannot help thinking that it must be a weak cause that needs such bolstering up, as it would seem from these statements. The field is a great one and the applications that will be made of the electrical forms of energy, to say nothing of those already made, make the distrust and antagonism caused by the methods of its advocates all the more deplorable.

As a sample statement of an enthusiast, and a very recent statement, too, it may not be out of place to quote Lieutenant Frank J. Sprague's paper before the American Society of Electrical Engineers. In contrasting the two motors, electric and steam, he spoke of the advantages of the electric and the disadvantages of the steam, which was perfectly natural and just, but not satisfied with this he stated that "break any one of the many parts in a locomotive and it is helpless."

Dr. Louis Bell made use of a similar statement before the Franklin Institute, but it in nowise helps the cause they represent, as any mechanic knows the

statements to be entirely without foundation. When the leading lights of the electrical fraternity give utterance to such statements, the lesser ones may be excused. It lies with the electrical press to inaugurate an era of fairness and justice, that will help their cause more than their present course and benefit the world by an increased usefulness of electric energy.

In railway service, and especially street railway, the tendency is to underrate the power necessary for the work. After seeing two poor specimens of horse flesh or mule meat dragging a car on the ordinary street roads, it is not an uncommon mistake to suppose that a 10 H.P. motor will be all that is needed. That this is a mistake the first steam and electric motor builders can testify. They have learned the lesson well and to-day the electric street car is usually equipped with two motors of 15 H.P. each, in order to have a surplus when the extra power is needed.

For street motors the steam engine is hardly in the race, and yet when the cost of running and repairs is compared with the electric motors on elevated and underground roads, it seems strange that there should be so few roads so operated.

The tests on the Ninth Avenue line in New York in 1889 by Lincoln Moss are well known, though to the discredit of the electrical journals be it said that they endeavored to brand them as unauthentic. And the comparative cost of operation of the Manhattan system and the London underground electric railway, as given by Mr. Day in a paper before the Chicago Electric Club also, shows a large balance in favor of steam used direct. With these facts well known, it seems strange that the steam motor is not more used on the suburban street railways, for on such roads the small amount of smoke and escaping steam necessary can hardly be called objectionable, for these can be much reduced from the ordinary practice, when it is necessary to do so.

The best paying road in the vicinity of Philadelphia, Pa., is said to be the Frankford dummy line, and if this line can be operated and show a balance on the profit side of the account, the additional profits of saving by the use of good motors would be considerable, for the poorest type of engines that can be found are used there.

A road of the kind mentioned, operated by locomotives, would form a good basis for comparison with the different forms of motors, a standard of comparison that is much needed. What has been said of street-car service is in the main true of all railroad service, the amount of power necessary for high speeds being far in excess of what might be supposed.

When it is considered that the modern locomotives develop over 1000 H.P. at times, and that 500 H.P. is an everyday and usual occurrence in ordinary practice, the 250 H.P. electric motor for railroad work that is being built by the Thomson-Houston Company, would seem to show that the power necessary for high speeds with any fair-sized train has not been reckoned high enough. This motor is designed to attain a speed of forty miles an hour, and comparing its rated horse power with that of the locomotives, it seems as though its small power must be detrimental to the accomplishment of its desired speed.

Power is not the only question to be considered in high speed, however, though the other considerations are rarely if ever mentioned by the high-speed enthusiasts. Lubrication of journals is among the most important considerations, as at the present rates of speed the most trouble comes from this source, and surely the adoption of electricity or any other form of energy will not materially aid in this respect, except as the motors may reduce the number of revolving or moving parts.

The talk about this or that motor not being able to do the work is often meaningless, as it is usually a question of power and mechanical construction, and not of the particular form of energy employed.

Whether steam, electricity, air, or any other form of energy is employed, it is only a question of having a sufficient quantity of power at command, and, having this, the particular kind of energy can generally be disregarded.

A NEW VERTICAL ENGINE.

ON the next page is printed an illustration taken from a photograph of the engine recently placed in the power-house of the Buffalo Street Railway Company. The general type of the engine is that of an inverted cylinder compound with two cranks set at 90°. The high-pressure cylinder is 17″ in diameter; the low-pressure, 33½″ in diameter, and the common stroke, 28″. The engine is designed for and is running 140 revolutions per minute, this speed of revolution occupying a position midway between the Corliss and the modern high-speed engines usually used for this work; the piston speed, however, is being kept at 600 feet per minute.

The engine is rated at 450 H.P., with 125 pounds initial steam-pressure, and should run equally well condensing or non-condensing. It is operated at present non-condensing, as the railway company's condenser-house is not yet finished.

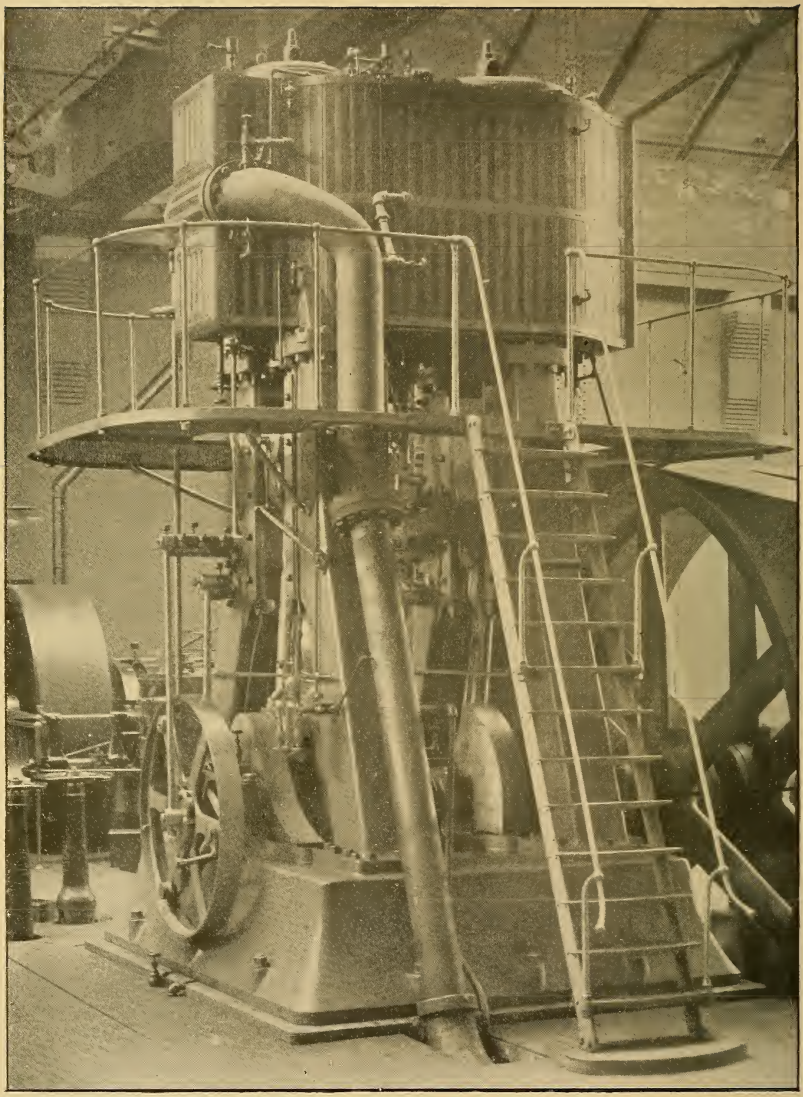
There are several new points in the design of this engine, one of the most important of which is the double-ported steam and exhaust-valves used for steam distribution. There are two steam and two exhaust-valves to each cylinder, both being operated independently, as in a Corliss, thus allowing different degrees of compression and cut-off. The valves are extremely light, perfectly balanced, and give a large port opening, which with a small valve is very noticeable when compared with the piston-valve which is used on this type of engine to-day.

In most marine engines using piston-valves in the high-pressure cylinder the diameter of the valve-chest is often as large, if not larger, than that of the high-pressure cylinder itself in a triple-expansion engine, and with the same style of valve used on the low-pressure it becomes necessary to use two and sometimes three different valves, locating the centers on a circle whose center is coincident with that of the low-pressure cylinder. On the low-pressure cylinder the admission-valves have a peculiar motion, by means of rocker-arms, giving them a quick movement at the point of the cut-off. The movement of the high-pressure admission-valve is controlled by a centrifugal shaft governor, by which means the engine is regulated as regards speed of revolution. This point of speed is, of course, a very important one in this class of work, and by means of this governor, which has only one weight, one spring, and four pivoted joints, its sensitiveness is very great, as is shown by the regulation of the engine in regular work not exceeding one per cent. under extreme changes of load. It is said some objections have been raised as to the advisability of governing an engine of this size by means of a shaft governor, but with the type of valves employed no difficulty has been met with and the engine is to-day operating very successfully.

The makers have given much care to the details of construction of these engines. For instance, the piston-rod and cross-head are forged in one piece and babbitted slippers fastened to the head of the rod, set out not by wedges but by liners only. The cross-head in the connecting-rod is forked, while the crank-pin end is of standard marine type. All bearings of the engine are babbitted, the main bearings having cast-iron shells lined with babbitt, about which shells is circulated water for keeping the temperature down in case of trouble, water being also circulated through the back of the guides for the same purpose.

The engine is lubricated entirely by means of grease; this lubrication is done automatically, the lubricant being forced through pipes running from the central reservoir to different parts or bearings of the engine. This system is similar to that of an accumulator in a hydraulic plant, weights being placed on the piston of the accumulator, forcing the grease to the respective parts of the engine, the flow of grease being controlled by stop-cocks at the various bearings.

The engine has been running for some time non-condensing, although really



500 HORSE-POWER VERTICAL ENGINE. BUILT BY THE LAKE ERIE ENGINEERING WORKS, BUFFALO, N. Y.

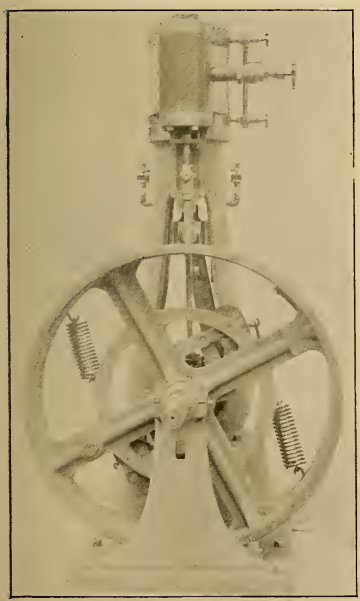
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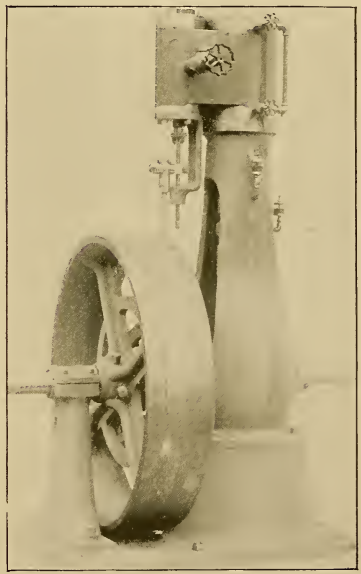
designed to be worked condensing, and has given perfect satisfaction, doing its work smoothly and with entire ease and there being notable absence of any hot bearings, so common with new engines on this class of work.

The engine is one of two which have been built by the Lake Erie Engineering Works, of Buffalo, for the Buffalo Railway Company, through their engineers, the Field Engineering Company, of New York, who designed and equipped the entire railway system in Buffalo.

SMALL VERTICAL ENGINES.

THE demand for small units in the application of power has led to the manufacture of many kinds of engines possessing more or less merit. One of the essential features of an engine of from 5 H.P. to 50 H.P. is that, besides being so constructed that it shall be economical in the use of steam, the space occupied shall be small, and the vertical engine seems to meet the necessity in a very satisfactory manner. One of the recent productions of an engine of this class is being built by the Racine Hardware Manufacturing Company, and illustrations are shown below. The rated capacity of this engine at 80 pounds steam, cutting off at





VERTICAL ENGINES BUILT BY THE RACINE HARDWARE MANUFACTURING COMPANY, RACINE, WIS.

¼ stroke, is 10 H.P. The details are as follows :

Diameter of cylinder, 6″.
Stroke of piston, 6″.
Speed at rated power, 350 revolutions.
Diameter of steam-pipe, 1¼″.
Exhaust-pipe, 1½″.

Diameter of shaft, 2¼″.
Crank-shaft, solid forged steel.
Number of bearings, 3 on self-contained base.
Total length of bearings, 16½″.
Diameter of crank-pin, 2″.
Length of crank-pin, 3″.
Diameter of cross-head pin, 1⅛″.
Length of cross-head pin, 2½″.
Area of cross-head shoe, 12″.
Length of connecting-rod, 17½″.
Balanced piston-valve diameter, 3″, with 5-16″ lap; area of port, 2½″.
Diameter of piston-rod, 1⅛″.
Diameter of governor wheel, 34″.
Total weight of engine, 1500 pounds.

At the Ohio University, at Athens, O., where one of these engines has been running for some time, Professor W. M. Stine has made a number of experiments, and writes that the engine in regulation and smooth running has proved very satisfactory, and in a future issue we may print some further data as to the steam consumption, together with actual diagrams he has taken.

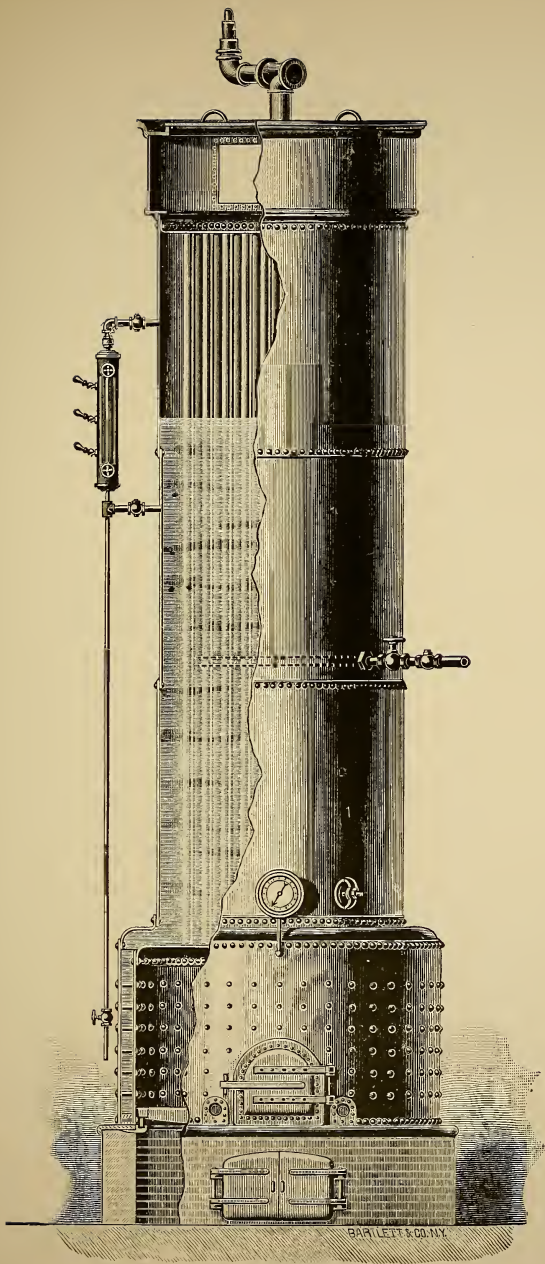
THE MANNING VERTICAL BOILER.

THE increase in the demand for a boiler which will occupy a small floor-space and which can be safely run at a high working-pressure, and at the same time give economy in the consumption of fuel equal to any of the best types of boilers on the market, has led to many new types, some of which are worthy of attention. Mr. C. H. Manning, a well-known mechanical engineer, the chief engineer of a manufacturing concern in Manchester, N. H., employing over 7000 horse power, some years ago obtained a patent for a boiler which is illustrated on the following page. This boiler has been built for some time by a number of firms, and recently the Phœnix Iron Works Company, of Meadville, Pa., made arrangements with the inventor to build them with but slight variation from the form of construction as adopted by other makers.

The illustration shows the construction of the boiler, which is fired internally, and as the shell is not exposed to the action of the fire it can be made of plates sufficiently thick to safely carry a very high pressure. The feature of an internally fired boiler has long been appreciated by engineers, and a boiler of this type is less expensive in the setting required than is an externally fired boiler, such as the horizontal tubular. These boilers are built of the best grade of flange steel, and the joints, riveting, and staying are such that a working pressure of from 140 to 175 pounds per square inch can be carried on them, according to the size of the boiler.

It will be seen that the fire-box is enlarged so as to admit of a grate surface in proportion to the tube surface. The tubes are 15 feet in length, and the water-line is carried within 4 feet of the upper head, giving thereby about 12 feet of water above the lower head, which water is subdivided by a large number of tubes, each of which is 2½ inches in diameter. The heat passes through the tubes, and in its passage through the long tubes of small diameter is well absorbed before passing out of the top of the boiler, so that the temperature of the escaping gases is but slightly above that due to the pressure of the steam. In practice this difference in temperature is about sufficient to superheat the steam 10 or 15 degrees. The heat, however, at the upper ends of the tubes is not sufficient to burn them, which is a source of great trouble in the ordinary vertical boiler where the tubes are short. It can readily be seen that if the heat generated in the furnace is by the long tubes of small diameter thoroughly absorbed by the water in the boiler a maximum efficiency results.

The expansion of the tubes is allowed for by the reverse flange at the lower end of the shell and at the top of the water-leg. The furnace is thoroughly stayed. In the operation of the boiler the ebullition is so rapid from the lower tube sheet that the sediment in



THE MANNING PATENT BOILER. BUILT BY THE PHŒNIX IRON WORKS COMPANY, MEADVILLE, PA.

the water is carried, or falls, to the lower part of the water-leg. At the bottom of the water-leg is a chain which passes completely around the furnace, and which is allowed to remain in the water-leg while the boiler is in operation. At each side of the fire-door is a hand-hole, and by removing these hand-holes and taking out each end of the chain, it can be racked back and forth, and in this way loosen the sediment which has collected in the water-leg, and enables it to be washed out by means of a hose. The boiler illustrated is 61 inches in diameter. The detail of construction is as follows: 184 2½ in. tubes; length of tubes, 15 ft.; thickness (shell) 7-16 in.; thickness (heads), ½ in.; fire-box (diameter), 72 in.; fire-box (height), 45 in.; grate-surface, 28.27 in.; heating-surface, 1888 in.; H.P. 10 square feet, 180; H.P. 12 square feet, 150; weight of boiler, 17,600 lbs.; weight of castings, 4300 lbs.

Reflections and Observations.

I MET the manufacturer of a well-known feed-water purifier recently and he told me a story which shows the great difficulty engineers at times have to obtain the consent of mill agents or owners to some necessary improvement.

It seems that for some years it has been found necessary to employ one or two men each Sunday to clean a battery of boilers in the mill in question, and the enterprising purifier-maker was doing all he could to convince the owners that it would be a good thing to adopt his method of keeping the boiler clean. "Why," he argued, "if you put this purifier in, you will almost save its entire cost the first year in labor, and besides, it will take so much less coal, for the boiler will be kept clean."

"Yes, I understand," replied the owner; "I have no doubt that your scheme is all right, but it's too complicated."

"You are mistaken. Why, this is the finest and least complicated purifier in the world."

"I have no doubt it is the finest, but I don't like complicated things. Now, some time ago my friends presented me with a beautiful watch, the finest thing in the world, the papers said; cost over $500 and all that. But what good is it? It's so complicated and winds up so easy I forget all about it sometimes. It gets out of order and I have to take it to a jeweler, pay him $10 or $15 to fix it, and all that, you know. Well sir, I don't carry it any more. Now, look at this 'Waterbury': cost me $2.75; never have any trouble with it; if it stops going I throw it away and buy another one. No bother—just the thing, you know."

"But it don't keep good time," interposed my friend. "If you had to catch a train, now, you couldn't tell much by it, could you?"

"Bless your soul, what of that? I never have any trouble finding a clock."

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I VISITED Cornell University a few weeks ago, and as the train sped along Cayuga Lake for over twenty miles I saw from the car window more wild ducks than I had ever seen before. The lake, owing to the mild weather, was not frozen over, which may account for the presence of ducks so late in the season. Without exaggeration, there were undoubtedly hundreds of thousands within a radius of fifty miles of the college. Of course the news spread, and sportsmen of all ages, sizes, and political

creeds were having a happy time. From the college I went to Buffalo, and a week later, when returning from New York, I met on the train a well-known engineer who told me a good story about the experience he had with a friend who started out with a big bag and plenty of ammunition (both kinds).

It seems that two days after hearing the ducks were around the sportsmen took a train and stopped at some small place along the lake. Something had happened to the ducks, however, for although the men wandered through bog and mire and over rocky roads for miles, not a solitary duck did they see.

They were very much disgusted, but of the two, Mr. Smith (I won't give you his correct name) was probably in the worst humor, for it seems he had stepped one foot up to his knee in the cold waters of Cayuga. They were about three miles from the station and were wending their way very wearily to take the first train that they could get for Geneva, when suddenly they came to a little pond upon the calm bosom of which were quietly resting about a dozen ducks. A man who had just emerged from the house near by was standing at the edge of the pond quietly smoking a pipe and gazing fondly upon the ducks. An idea suddenly occurred to Mr. Smith. Going up to the man, he said,—

"My friend, what will you take to let me have a shot at those ducks?"

"A shot at ther ducks?"

"Yes, just one shot."

"Well, I ain't perticul'r, but hand out a doller and bang away."

Without any delay, Smith put the gun to his shoulder and with the thought of the beautiful ducks, soon to be his, a smile lit up his countenance. Bang, bang!—his aim was good and the pond was strewn with the dead and dying. Turning to the man he handed him another dollar, with the remark,—

"You didn't think I would do as well as that, did you?"

"Well," replied the rustic, pocketing the coin and removing the pipe from his lips, "I don't kere how many you kilt, but if yer want them 'ere ducks you better pick 'em up lively now, for the man that owns 'em is just comin' over the hill."

THERE are few people who have ever seen an indicator-card being taken from a locomotive, and it almost frightens one to think of the man who does work of that sort. Immediately above the cylinder is rigged a seat with a board for him to lean his back against, while the train thunders along 60 or 70 miles an hour. Very few railway companies have ever taken the trouble to ascertain the condition of the valves on the locomotives they own, but the Pennsylvania company, with its 14,000 miles of railway, long ago realized what room there was for economy in their coal bill, and are constantly trying to see what can be accomplished in this line.

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SOME time ago they inaugurated a system of profit-sharing with the engineer and firemen. After ascertaining the amount of coal used for certain runs and certain trains, they arranged to divide the amount saved with the men in charge of the engine. Some idea of the possible economy can be gained from the fact (which I have obtained from an authentic source) that in one week's run of a certain train the amount drawn, in addition to their salary, by the engineer and firemen, was over $20 each, which would show a total saving of some $80 in coal, or a net gain of $40 on that one locomotive to the railroad, —over $2000 a year.

While this ratio of economy would not hold on many locomotives owned by that company, a saving of but one or two tons a week on each engine would mean a saving of hundreds of thousands of dollars yearly. This is accomplished by careful firing and close attention to the engine, and if a similar idea was carried out in manufacturing establishments, without doubt the "man who pays the coal bill" would not find it necessary to draw as large a check to make the wheels "go 'round."

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JUDGING from a paragraph which I saw in the San Francisco *Argonaut*, its editor must have been in a squeeze of some sort where a mining engineer had a hand. It says that, as is known, expert

witnesses are allowed to give their *opinion* as evidence, and are out of the reach of an indictment for perjury, which always hangs over the head of the ordinary witness, who can testify to fact only. Apropos of this, there used to be a saying current years ago, of a judge who recognized three degrees in liars: the liar simple, the d—d liar, and the expert witness. There is another version which is of interest—namely, the three degrees of liars, which are said to be the liar, the d—d liar, and the mining engineer.

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CONSIDERABLE has been written and said recently about the practicability and advisability of making the Erie canal a ship-canal. When the Erie canal was in course of construction, Governor Clinton visited Lockport, which its citizens at that time dreamed was to be the great inland city of the continent. Buffalo was hardly born. Lockport was to be the key of the commerce that was to flow through it, and, with its vast water-power, the seat of the great flouring mills and manufactories north of Mason and Dixon's line. Governor Clinton did not throw any cold water on their enthusiasm, but ventured to say that New York city would derive immense advantages from the canal. Some of the wiseacres shook their heads and said, "Too far from Lockport, governor—too far from Lockport."

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SOME years ago an English engineer, now prominent in the official management of one of our great railroads, was superintending the construction of a new road in Pennsylvania. After supper one evening he strolled into the "settin'-room" of the country tavern, where some twenty men were seated around the stove, smoking and chatting. A regular down-East Yankee was expounding the remarkable strength of the arch, its use and application in mechanics, and illustrating his remarks by pawing a half-bushel measure.

"You ain't no idee," said he, "how strong the arch is if ye set it right—if ye know how. Now there's the egg—nothin's got a prettier arch than the egg, and if you set it right it's mighty strong. Why, I kin set an egg on this floor in sich shape that ye cant't break it with this half-bushel measure."

A general murmur of sneering disbelief ran around the room; but the Yankee was game.

"I said I kin, and I kin, and I'll bet the drinks for the crowd on it."

The engineer hated a Yankee, and though a reserved man, he could not permit a Yankee to bluff a whole party with such an arrogant and preposterous statement, so he quietly said,—

"I will take that bet."

An egg was brought in from the kitchen and handed to the Yankee. He took it and stood it upon the floor in the corner of the room where the measure couldn't reach it.

The engineer did not even attempt to fill a square corner with a round measure, but paid for the drinks and retired, sadder and wiser.

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SOME of the waiters at the Leland Hotel in Chicago have very good memories, and a guest having been absent for several years is instantly recognized. Like the hotel clerk, however, their memory fails them, but like him, also, what they lack in memory they seem to make up in diplomacy.

While seated at the table one day recently a gentleman who is a well-known engineer came in, and as he sat down the dusky head waiter said,—

"Very fine day, governor."

"Yes, it is a very fine day; but I'm not a governor, I regret to say."

"Mistakes will happen, senator," replied the waiter.

"Yes, mistakes will happen; but I'm not a senator, either."

"Well, my mem'ry is getting bad; but I remember you now, kernel."

"Well, I'll help you out, for I am not a colonel, either. I'm only an engineer at the World's Fair."

"That's so," added the waiter; "I couldn't exactly place you, but I knew you were top of the heap somewhere."

—*The Observer.*



EDWIN REYNOLDS.

CASSIER'S MAGAZINE.

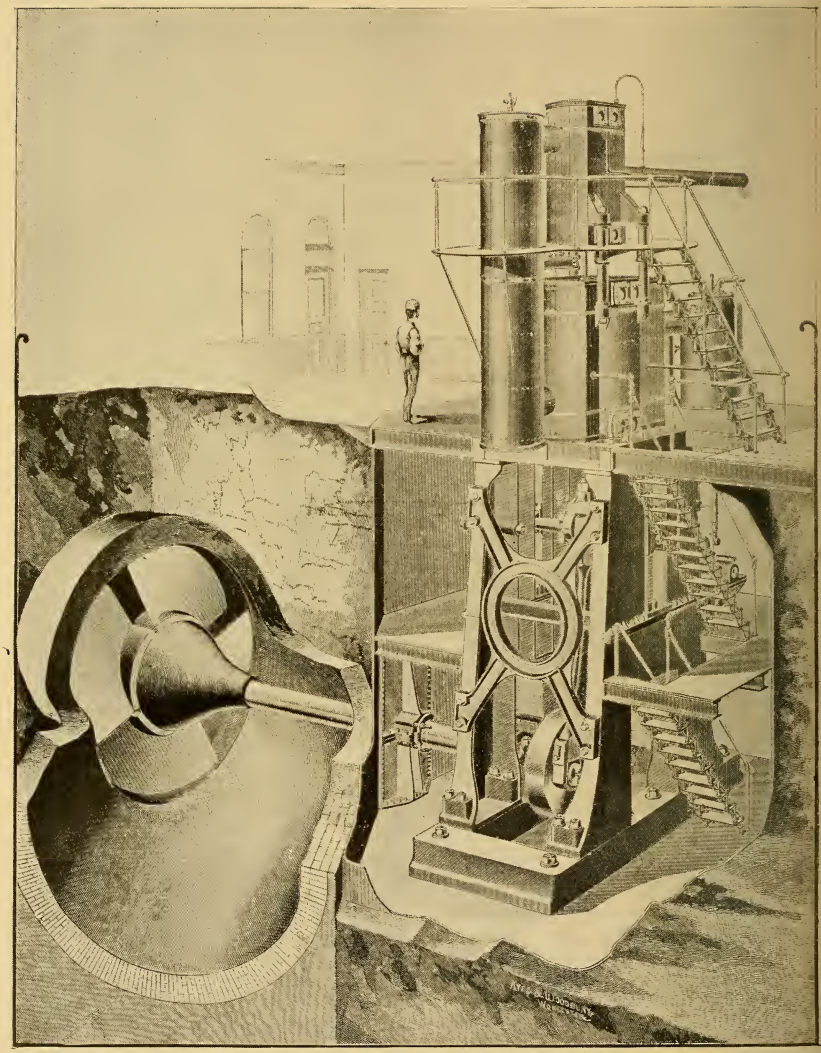
VOL. I. MARCH, 1892. No. 5.

EDWIN REYNOLDS, THE ENGINEER.



THE early settlers of Rhode Island numbered among them one William Reynolds, from Gloucestershire, England, who located at North Kingstown in 1636, and in 1637 was at Providence, and received his share, in the first divisions to white men, of the land on which the city of Providence now stands. From him descended in direct line Christopher Reynolds, who was born in Frenchtown, R. I., July 11, 1790, and who removed to Mansfield, Tolland county, Conn., about 1809 or 1810. At Mansfield he married Charissa Huntington, and at Mansfield, March 23, 1831, was born Edwin Reynolds, who by years of honorable effort has reached a foremost position among the mechanical engineers who have contributed so largely to the wealth and prosperity of this country. One of his ancestors on the father's side, Theophilus Whaley, was an officer in Cromwell's army and was present at the execution of King Charles I; another, Hero lias Hicks, a Quakeress, suffered the lash and imprisonment by order of Governor Endicott, of Massachusetts, because of her religious opinions. On the mother's side, also, Mr. Reynolds comes of old New England ancestry; so it will be seen that the independence of spirit, honesty of purpose, strength of character, sterling integrity, indomitable energy, and unfailing perseverence so characteristic of the sons and daughters of New England are his by rightful inheritance. Endowed by nature with a large measure of ability, while still a boy he turned intuitively to mechanical pursuits, and has followed the bent of his earlier years with a persistency and singleness of purpose that have resulted in such striking and well-merited success.

After receiving an ordinary common-school education, Mr. Reynolds was apprenticed to the machinist's trade in Mansfield, Mass., in 1847. After serving a three years' apprenticeship, he worked in various shops in Connecticut, Massachusetts, and Ohio until 1857, when he removed to Aurora, Ind., and became superintendent of the shops of Steadman & Co., whose principal work was the building of engines, saw-mills, and drainage-pumps for Mississippi plantations. This business was seriously interrupted by the outbreak of the rebellion, and in the spring of 1861 Mr. Reynolds returned to Connecticut. From this time until 1867 he was variously engaged, principally in New York and Boston. In 1867 he removed to Providence, R. I., and entered the employ of the Corliss Steam Engine Company. Four years later he became general superintendent of the Corliss Engine Works, in which position he remained until July, 1877, when he resigned and removed to Milwaukee to take the position of general superintendent of Edward P. Allis & Co.'s Reliance Works, which position he still holds. In his new position, his manly character, not less than his mechanical ability, soon won for him the confidence of Mr. Edward P. Allis,



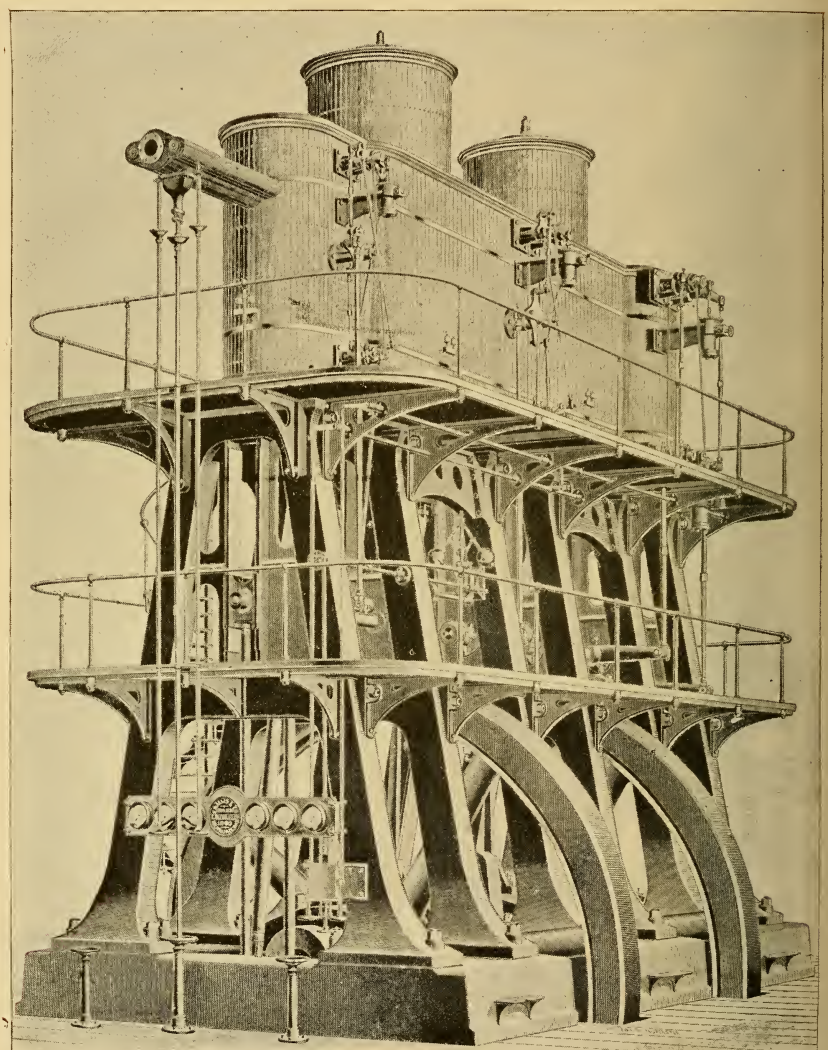
REYNOLDS SCREW PUMPING-ENGINE FOR FORCING CLEAR WATER INTO THE MILWAUKEE RIVER.

owner of the works, a confidence which grew stronger as years passed. When Mr. Allis died, some two years since, Mr. Reynolds was, by his will, named as one of the trustees of the estate, and a year later, when the business was reorganized and the present company formed, he became one of the directors and second vice-president. He is also president of the Daisy Roller Mills, president of the Milwaukee Boiler Company, and president of the Morning Mining Company. This in brief is an outline of the history of the man who has risen by his own unaided efforts, step by step, from an apprentice in a small machine shop, to be the mechanical head of one of the largest engineering establishments on the Western continent, and who, by the work that has come from his hands, has won a world-wide reputation.



RESIDENCE OF EDWIN REYNOLDS, AT MILWAUKEE, WIS.

As an engineer, Mr. Reynolds fills to perfection the ideal of a recent writer, who says that the word engineer in its best sense means a man who is competent, full of resource, of indomitable energy and industry, and that such men are born, not made. As an engineer, he is remarkable not less for his originality and daring than for his conservatism and caution; the latter reaches the line of timidity, the former never carries him to the extreme of rashness. But with all this conservatism and regard for principles well tried in his long experience, he does not hesitate in a radical departure from established practice when his judgment, based upon his experience, commends it. Having first convinced himself that he is right, he holds to his opinions tenaciously in the face of all adverse criticism. As the result he has been uniformly successful and has made a very strong impression upon the engineering practice of the present day. Many instances might be cited to show, not alone his ability as an engineer, but



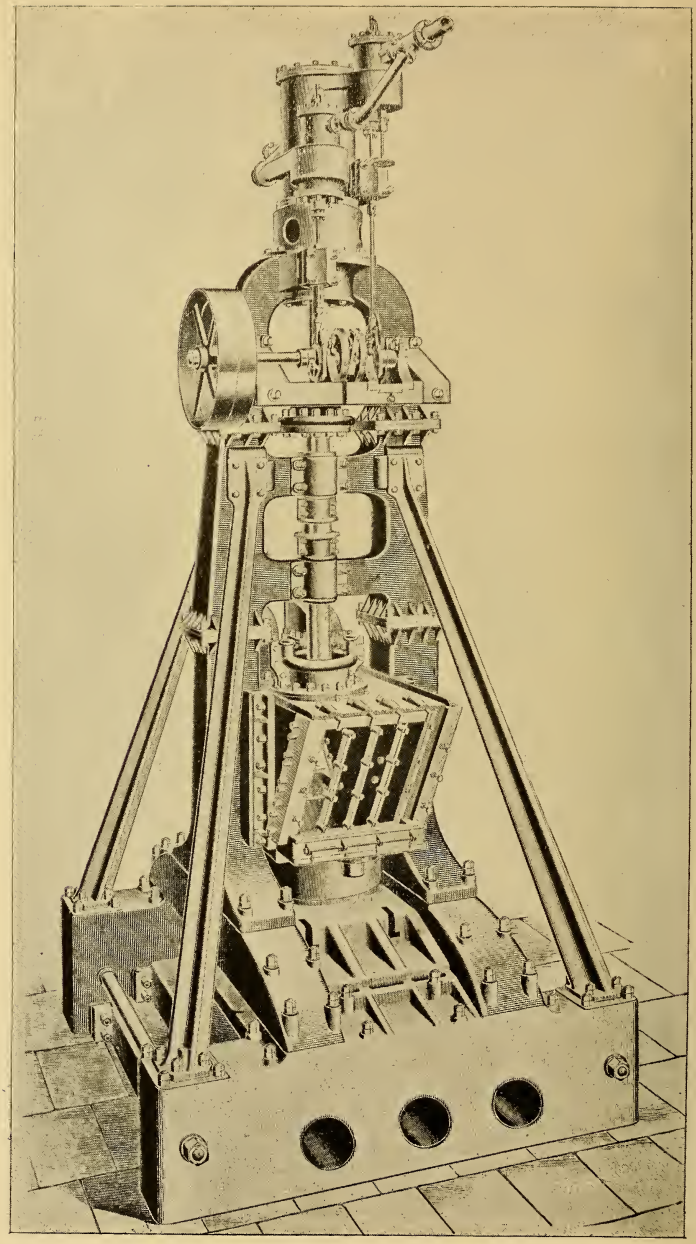
REYNOLDS TRIPLE-EXPANSION PUMPING-ENGINE CONSTRUCTED FOR THE AMERICAN WATER-WORKS COMPANY, AT OMAHA, NEB.

also his position as a leader in engineering practice.

To Mr. Reynolds belongs the credit of building the first triple-expansion pumping-engine ever constructed for water-works purposes. This engine was similar in design to the machine illustrated here, though much smaller, and was built in 1888 for the Milwaukee Water-Works. The duty guaranteed was 115 million foot-pounds for each 100 pounds of anthracite coal burned, and as the steam-pressure allowed by the city authorities was only 80 pounds predictions were freely made that the machine would be unable to fulfill the guarantee. On the official trial the engine considerably exceeded the guaranteed duty, although operated under exceedingly unfavorable conditions, and has shown a duty as high as 129,000,000 foot-pounds and developed an I. H. P. on $13\frac{84}{100}$ pounds of feed-water per hour, a result which perhaps will surprise engineers who claim that there is no economy in the use of triple-expansion engines with steam-pressure of less than 140 to 160 pounds. The triple-expansion pumping-engine illustrated is one of five built for the city of Chicago during the last two years. These machines have a capacity of fifteen million gallons each, in 24 hours, raised 125 feet, and are supplied with steam at a pressure of 120 pounds per square inch. The steam cylinders are 27, 46, and 70 inches diameter respectively, all being 5-foot stroke. The pump-plungers are $23\frac{3}{4}$-inch diameter by 5-inch stroke, and the engines are operated at from 16 to 18 revolutions per minute. The cylinders are fitted with Reynolds Corliss valve-gear, especially arranged for this type of engine, having adjustable trip cut-offs on each cylinder, the high-pressure valve-gear also being under the control of a speed regulator. The pumps are of the single-acting outside packed plunger type, and are fitted with a peculiar arrangement of rubber valves, the valves being of small diameter and light lift and being mounted in groups on "cages." These machines weigh about 420 tons each.

On the official trial of two of these engines at West Harrison Street Station, the duty obtained was 140 million foot-pounds for each 1000 pounds of steam used, and the steam consumed per indicated horse power per hour was $12\frac{67}{100}$ pounds, showing an economy in the use of steam beyond that shown by any other engine of any description as far as is known. The largest machine of this type was constructed for the American Water-Works Company for their Omaha plant, and has a capacity of 18 million gallons per 24 hours raised 310 feet, the steam cylinders being 40, 70, and 104 inches diameter respectively, and this machine is, all things considered, probably the largest pumping-engine in America.

Another instance in which the judgment of Mr. Reynolds has been amply upheld is found in the Milwaukee, Wis., flushing tunnel and pumping-engine. The project for this important work met with his hearty support from the first, and its final adoption in the face of strong opposition was due as much to the confidence reposed in his judgment as to any other one cause; while the plans for all the machinery, both in general and detail, were furnished by him, including the gates and everything between them. This engine, of which an illustration is shown, is of an entirely novel type and was designed by Mr. Reynolds and constructed for the city of Milwaukee in 1888. The machine has a rated capacity of 32,000 cubic feet per minute or about 345 million gallons in 24 hours, raised $4\frac{1}{2}$ feet high, but in actual operation the amount pumped varies between 400 and 500 million gallons in 24 hours. As will be seen, the pump is of the propeller type, the diameter of the propeller being 14 feet and the pitch 8 feet. The wheel is located in the mouth of a 12-foot tunnel, and the plant is employed in forcing clear water from Lake Michigan into Milwaukee river during the summer months for the purpose of purifying the river water, and is capable of renewing the entire amount of water in the river every 18 hours. The pump is driven by a vertical steeple compound engine. The duty guaranteed for this machine was 70 million foot-pounds for each 100 lbs of coal burned, and the duty obtained at the official trial was 76 million foot-pounds, without deductions of any kind, the



REYNOLDS ORE STAMP IN USE AT THE LAKE SUPERIOR COPPER MINES.

efficiency of the wheel being 86¾ per cent. and the steam consumption of the engine 14.07 pounds per I.H.P. per hour. The construction of the wheel was entirely original with Mr. Reynolds, and the efficiency shown places it far ahead of centrifugal pumps for handling large quantities of water under comparative low lifts.

With characteristic modesty Mr. Reynolds has kept silent regarding this important work, and much of the credit has been claimed by others, while in fact it belongs to him alone. It is only simply justice, but none the less a pleasure, to "Render unto Cæsar the things which are Cæsar's" and place the honor where it properly belongs.

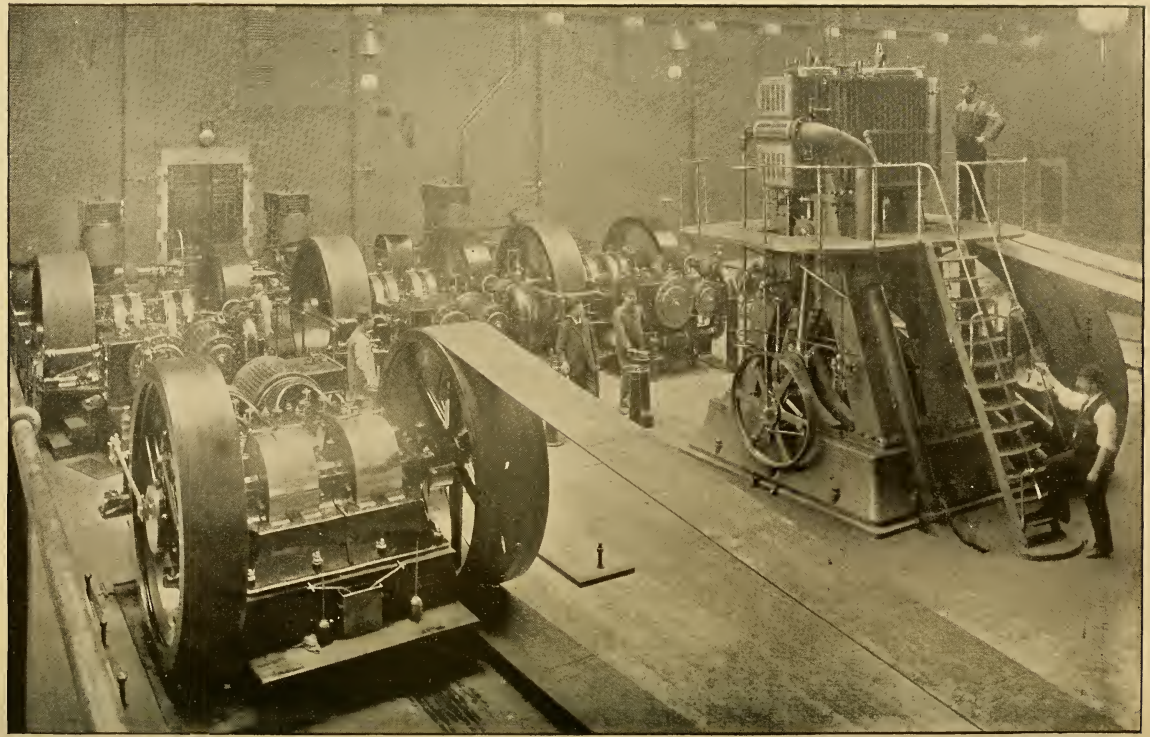
The steam stamp illustrated is of a type employed by the Lake Superior copper mines for crushing copper-bearing rock.

Until the last few years all steam stamps were constructed with the anvil block and mortar resting on heavy timbers, which were supported at the ends only. These spring timbers, so called, were supposed to be essential to the operation of the machine, being claimed by experts that with solid foundations the stamps could not be made durable and would not crush as much rock as with the spring timber bottom. In defiance of these theories, Mr. Reynolds proposed the construction of a stamp having a solid cast-iron foundation, and his proposition having been accepted with a guarantee of at least equaling the spring-bottom machines, he built the machine illustrated. When put in operation the stamp with the solid foundation crushed about 50 per cent. more rock in 24 hours than machines of exactly similar size and construction but which sat on spring timbers, the result of which was that nearly all of the old machines having spring bottoms have had them replaced with solid anvil blocks. Aside from the gain in the capacity of the machine the substitution of solid bottoms has done away with the expense of the renewal of the spring timbers, which on the old machines are required frequently, the life of the timbers depending largely on the weight of the stamp and the blow struck. These machines have a steam cylinder 20 inches diameter, 24 inches stroke, and are fitted with balanced piston-valves. The valve-gear is driven by a belt from the line-shaft and the valve-gear has no direct connection with the steam piston and the stamp shaft, the movements of the steam piston following the valve-gear. The lower valve admits steam under the piston at a reduced pressure for lifting the weight of the ram only, while the upper valve admits steam at boiler-pressure above the piston for striking the blow. The eccentric for the lower valve is on the driving shaft and has a uniform rotary motion, but the eccentric for the upper valve has a slow advance and quick return so as to obtain a cut-off and thus to work the steam expansively. This motion is obtained by the use of a device somewhat similar to the Whitworth quick return.

The two shafts being connected together by a drag-link with the driven shaft carrying the upper eccentric set out of line with the other shaft, this produces the desired motion, the irregularity varying according to the distance the shafts are out of line with each other. The whole device is extremely simple and thoroughly effective. The records show that these stamps crush on an average 300 tons of amygdaloid copper rock per 24 hours and 280 tons of hard conglomerate copper rock in 24 hours at an expense of about 35 cents per ton of amygdaloid and 48 cents per ton of conglomerate rock, including the entire cost of operating the stamps, mill, pumping water, etc.

As a pioneer in building high-grade engines in the West, it was freely predicted he would fail; now the establishment of which he is the mechanical head is the largest engine-building works in the United States.

Mr. Reynolds, it may be added, was the pioneer in the introduction of the compound engine for use in manufacturing establishments. The compound engine designed by him and placed in the Eagle Mills in Milwaukee in 1878 was one of the first large compound engines in America to be used for manufacturing purposes.



BALL ENGINES AT THE POWER-HOUSE OF THE BUFFALO STREET RAILWAY COMPANY, BUFFALO, N. Y.

CENTRIFUGAL FORCE AND RESULTING PHENOMENA.*

By Charles E. Emery, PH.D.



THE comparative frequency of accidents to the fly-wheels of steam-engines during recent years has impressed the speaker with the desirablity of an investigation of the general subject of centrifugal force, particularly the limitations which it imposes on the design of pulleys, fly-wheels, and other machinery, and the influence it will have in the near future on the speed of railway trains. It is proposed to illustrate the destructive effects due to centrifugal force by photographic representations of machinery and buildings injured in this way, and finally to state in general terms some features developed during recent litigation on the subject which it is thought will be of interest to students of mechanical and electrical engineering.

The greater frequency of fly-wheel accidents of late years can in part be traced to the comparatively high speeds at which engines are now being operated, but more especially to the higher strains on material now found desirable under the spur of competition to produce increased work in engines of a given size by the use of higher steam-pressures. It does not appear that fly-wheels of customary construction should be unsafe at the comparatively high speeds now in common use, if proper materials were always used in construction. The weight of evidence is, that the factor of safety of fly-wheels operated at the low speeds formerly in vogue was so high that fly-wheel disruptions were very infrequent, and that therefore no special care was taken to secure superior designs, materials, and workmanship. It is a curious fact, also, that all the handbooks, as well as most of the text books the writer has consulted, either fail to point out the manner in which the formula for centrifugal forces should be applied in calculating the ultimate strength of a fly-wheel to resist centrifugal force or actually make such misapplication of the rule that the resulting disrupting force shown is over 4½ times as great as it should be, so it is believed that designs have frequently been based on the performance of other wheels, rather than the formulæ in the books. Some of the more elaborate works on applied mechanics and the recent and most excellent work of Professor Thurston on the steam-engine, however, contain a full discussion of the object with resulting formulæ which correspond, by changing the notation, to those hereinafter deduced without the aid of the calculus on the principle of fluid-pressure. The errors used in the old formulæ were fortunately on the safe side. All the rules agree as to the value of the centrifugal force due to swinging a single weight around a center, as in slinging a stone, and all will show the same strain on the string of the sling. The centrifugal force in this case is, as is well known, equal to the weight multiplied by the square of the velocity of such weight in its circular path in feet per second and divided by 32.16 times the length of the string or the radius of the circle. 32.16 is the value of the acceleratrix of gravity, usually designated by g, for the latitude of 42°; 32.2 being more nearly accurate for the latitude of London. In designing fly-wheels it is customary to consider that the rim is of itself sufficiently strong to resist disruption from centrifugal force without assistance from the arms. The desirability of doing this will be discussed later. The error introduced in

*A lecture delivered at Sibley College, Cornell University, January 23, 1892.

many of the handbooks arises from calculating the centrifugal force from the weight of the entire rim by the rule above given, whereas it is evident that only the weight of one-half the rim pulls against that of the other half to produce disruption along any particular diameter, so the result should be divided by 2, and again the centrifugal force produced by each half rim is resisted by double the sectional area of the rim, or by the sections at the two ends of the diameter, so the result should be again divided by 2, or by 4 in all, to find the unit strain on this basis. This result is still, however, 57 per cent. too large, for the reason that all the elementary weights in a half ring do not act at right angles to any diameter to produce rupture, but each pulls radially outward, so the resulting strain is exactly the same as that arising from fluid-pressure within the shell of a steam boiler. In the latter case the strain on the double thickness of shell is, as well known, equal to the pressure on one inch of width multiplied by the diameter in inches, so if we consider the rim of a fly-wheel or any pulley as a series of segments connected together at their edges, each, say, one inch wide at the outer end of radius of gyration, the total disruptive force at any diameter is equal to the sum of the components of the centrifugal forces produced by all the segments in a semi-circumference, or to the centrifugal force produced by one segment multiplied by the diameter, and not by the semi-circumference. The disrupting force thus obtained is resisted by two thicknesses of metal, so the result must be divided by double the section of the rim in square inches in order to obtain the unit strain on the material. In a fly-wheel or pulley-rim, however, the section which causes the weight is also the section which resists disruption. The width of the rim makes no difference, as each inch of width increases the weight and also increases the section. This is also true of the thickness, except that increase of thickness slightly increases the effective diameter. It therefore follows that the force which will disrupt a fly-wheel is independent of the actual weight, width, or thickness of section, and only varies with the tensile strength of the material, the unit weight of the same, and the square of the velocity.

FORMULÆ FOR CENTRIFUGAL FORCE APPLIED TO FLY-WHEELS, ETC.

W = Weight considered in pounds.

W_1 = Weight of segment of rim one inch thick in pounds.

Q = Centrifugal force in pounds.

Q_1 = Centrifugal force of segment one inch thick in pounds.

S = Strain per square inch of section in general in pounds.

S_1 = Strain per square foot of section in pounds.

S_2 = Strain per square inch of section of cast-iron in pounds.

S_3 = Strain per square inch of section of wrought-iron in pounds.

S_4 = Strain per square inch of section of steel in pounds.

A = Area of rim section in square feet.

v = Velocity in feet per second.

V = Velocity in feet per minute.

r = Radius of gyration in feet.

G = Weight of metal per cubic foot.

F = Disrupting force in pounds

$g = 32.16$ = Acceleratrix of gravity in pounds.

$$(1).\ Q = \frac{Wv^2}{gr} \qquad (3).\ v^2 = \frac{V^2}{3600}$$

$$(2).\ W_1 = \frac{GA}{12} \qquad (4).\ S_1 = 144\,S$$

$$(5).\ F = 2\,AS_1 = 2\,r \times 12\,Q_1 = \frac{2\,r \times 12\,W_1\,v^2}{gr}$$

$$(6).\ S = 0.00000006\,GV^2 = \frac{6\,GV^2}{10^8}$$

$$(6a).\ S_1 = \frac{G\,v^2}{g}$$

For cast-iron $G = 450$, so

$$(7).\ S_2 = 0.000027\,V^2 = \frac{27\,V^2}{10^6}$$

$$(8).\ V = 192.5\sqrt{S_2}$$

$$(8a).\ v = \sqrt{\frac{g}{G}\,S_1}$$

For wrought-iron

$$(9).\ S_3 = 1.067\,S_2.$$

For steel

$$(10).\ S_4 = 1.088\,S_2.$$

Referring to the notation and formulæ above, Eq. 1 will be recognized as the general formula for centrifugal force. The velocity, it will be understood, is that due to a diameter equal to the double radius of gyration of the section or for approximate work to the external diameter of pulley less the average thickness of rim. By Eq. 2 the weight of a segment or radial slice one inch thick at end of radius of gyration equals the volume, or $\frac{1}{12}$ of the area in square feet. By Eq. 5 the disrupting force, F, is made equal to twice the section, A of rim multiplied by the tensile strength, S_1, of material, which result equals twice the radius r, or the diameter, multiplied by 12 to reduce to inches into the centrifugal force Q_1, due to a single segment, on principles above explained. The value of Q is substituted in the last number from Eq. 1, writing W_1, for W. By combining with Eqs. 3 and 4 we easily obtain Eq. 6, and substituting in the weight G = 450 of a cubic foot of cast-iron we observe from Eq. 7 that the tensile strain, S_2, per square inch of section of a cast-iron rim may be found by multiplying the square of the velocity of the rim in feet per minute by 27, and pointing off six places of decimals. Eq. 8 is evidently derived from Eq. 7. Wrought-iron and steel are a little heavier than cast-iron, which may be considered by the corrections stated in Equations 9 and 10. In Eqs. 6 or 7 by making S or S_2 equal to the ultimate tensile strength of the material, the value of V will represent the velocity at which the rim should be disrupted. While good gun-iron has a tensile strength of 40,000 pounds per square inch and upward, and ordinary castings generally have a tensile strength of 15,000 pounds, it is thought best to consider the ultimate tensile strength of cast-iron pulleys as 10,000 pounds per square inch, for the reason that pulleys cast in one piece are subject to internal strains, and even fly-wheels and pulleys built up of pieces are liable to have blow-holes in some part, and generally also the fastenings are not equal in strength to the solid rim. On the basis of 10,000 pounds tensile strength the rim of a cast-iron wheel should, according to Eq. 7, be disrupted when its velocity has reached 19,235 feet, or 3.64 miles per minute. Ordinarily the rim velocity of fly-wheels is less than a mile a minute, but in some cases it is higher. With 6083 feet or 1.15 miles per minute the strain on rim is only 1000 pounds per square inch of section. Evidently if this is practically the limiting strain used for a cast-iron fly-wheel rim, it should not be exceeded on a cast-iron car-wheel, the better material used being required to offset the effect of jars and internal strains due to chilling the faces. Cast-iron car-wheels should not, therefore, be run at a higher speed than 1.15 miles per minute or 69 miles per hour. The factor of safety at this speed for both the fly-wheel and car-wheel would be 10 to 15 for 10,000 to 15,000 pounds tensile strength. The same factor of safety for a wrought-iron or steel rim would permit a unit strain of 5000 pounds per square inch and a rim speed of 201 miles per hour, so that the dreams of the electrical engineers need not be disturbed by fears of the influence of centrifugal force, at least if kept within the limits of doubling or even more than trebling the present speeds of railroad trains.

Recurring to the effect of the arms of a wheel on the result, it should be borne in mind that they are also influenced by centrifugal force, which increases with the weight required to increase their strength. If it be considered that the outer attachments of arm to arm of a built-up fly-wheel are such that the center of gravity of the arm is at half its length from center of shaft to rim of pulley, the united strain will be exactly half that shown in Equations 6 and 7 for the rim, so by calculation half the strength is available to strengthen the rim, or a trifle more if the fly-wheel centers are relatively large. The arms, however, are subject to transverse strains, if not from belts at least from changes of speed, and there is, moreover, no certainty that the arms and rim will be adjusted so as to pull exactly together in resisting disruption, so the plan of considering the rim by itself and making it strong enough to resist disruption by centrifugal force within safe limits, as is assumed in the calculations above, is altogether the safer way.

The destructive energy developed by the disruption of a large fly-wheel is illustrated by a very complete set of photographs of the ruins resulting from the destruction of a large fly-wheel in the Amoskeag Mills, at Manchester, N. H., which took place on the 15th of October, 1891, the photographs being kindly furnished by Past Assistant Engineer Charles H. Manning, U. S. N. (retired), the superintendent of the company. This company has a series of mills distributed along both sides of the Merrimac river for a distance of a mile and upward, the machinery of which is operated by water power during the season the same is available, and by large engines at other times. Much of the time the engines are connected to part of the water-wheels and supply any deficiency in the power of the latter. The engineering features are on a large and interesting scale. For instance, a large boiler-house is located on the west bank of the river, from which steam is conducted through a pipe laid across the river on a special bridge to engines on the east side, and the exhaust brought back through another pipe on another bridge. The engine to which the accident occurred was of the double Corliss condensing type, with 36-inch cylinders, rated at about 2000 horse power. The steam-pressure was 95 pounds per square inch. The normal speed of engines was from 60 to 61 revolutions per minute, and they were furnishing just previous to the accident 1900 to 1950 horse power, independent of a light water power connected to the same shafting, which was considered, under the conditions, insufficient to materially increase the speed. The fly-wheel was 30 feet in diameter and had something more than 9 feet face. It carried three belts, one 24 inches wide running to the westward and connecting to a jack-pulley on a shaft leading northerly to operate mills 7 and 8, the other belts each 42 inches wide, arranged on either side of the former, running to the eastward and connecting to two separate jack-pulleys on a shaft leading southerly and operating mills Nos. 3 and 4. The first difficulty observed was the slowing of the speed of the looms in mills 3 and 4, due, according to some accounts, to some derangement of a tightening pulley on one of the 42-inch belts. The operatives, therefore, as per standing orders, stopped the machinery, which, according to the finding of the coroner's jury, relieved the engines of 1500 horse power which causes them to accelerate their speed, the governor not controlling them as promptly as was customary. This increased speed quickened that of the looms in mills 7 and 8, and all but one were automatically thrown off, thus relieving the engine of 300 horse power more and causing the speed to increase still more. The engineers quickly detected the increased speed and commenced closing the throttles, but when one was entirely closed and the other practically so, the fly-wheel was suddenly disrupted, killing one of the engineers, wounding another, and cutting a broad swath in the roof and walls of the engine-room and those of an adjoining building to the westward, the basement of which was used as a pump-room, and the upper part as a "drawing-in" room, and causing the death in the latter room of two operatives. Let us approach these buildings from the outside, first looking at the west side of the pump and drawing-in building in which the operatives were killed. The result of the accident was, that a broad opening like a portal was cut through the wall of this building as well as through the wall of the adjoining engine-room. The large pipe at the foot of the break is the main exhaust-pipe used for heating purposes, which may be utilized as a steam pipe from the boiler-house across the river via the north bridge.

We then look from the outside at the east side of the engine-room. Here the destruction is more complete. A broad opening is cut in the wall and roof, and we see that a portion of the latter on either side of the cut has tumbled in. We see in the background the top of the large opening previously observed in the west wall of the pump and drawing-in room.

We now step inside the engine house and look from a point considerably to the left of the engines, where the opening through the west wall is not in sight, and view the wreck. On either side fragments of the roof still remaining in

place are seen, and the ground is strewn with bricks, timber, and material of all kinds. The large vertical pipes to the background at the left belong to the Buckley jet condenser, in which the vacuum is produced by a tall water column instead of an air-pump.

It has been previously stated that one loom in mills 7 and 8 did not stop. Careful tests were made with this loom to ascertain the speed at which the automatic stopping apparatus would operate, from which the coroner's jury decided that such loom could not at the time of the disruption of the fly-wheel have been making more than 170 to 175 picks per minute, corresponding to 72 to 74.1 revolutions per minute of the engine. According to the rule previously given for a cast-iron wheel 30 feet outside diameter, or, say, roughly 29¾ feet, for the double radius of gyration, disruption should not have taken place at less than 205.8 revolutions per minute, even if the average tensile strength of the rim section was only 10,000 pounds per square inch. It is natural to suppose, therefore, that the wheel failed from defects in construction of material. The face was very wide for one set of arms, and therefore weak to resist lateral strain. There would have been some side strain if one only of the 42-inch belts became slackened, but it would seem quite insufficient to cause the breakage. The disruption was, however, readily accounted for by the defects in the castings. Very large blow-holes were found in many of the same, and samples of the material varied in ultimate tensile strength from 15,000 down to 1000 pounds per square inch, showing clearly that the wheel had been running for a number of years with a dangerously low margin of safety, and that it was finally disrupted under an increase of strain of trifling importance in comparison with its supposed ultimate strength, and under conditions very much less exacting than those occurring regularly many times in a day or even in an hour with engines of a similar kind subjected to variable loads.

We will now turn our attention to a wreck caused by the disruption of the fly-wheel of a compound Corliss condensing engine employed to operate a portion of the electric lighting machinery in the electric station of the Electric Light and Gas Company of Lynn, Mass. The engine was provided with cylinders 20 and 36 inches in diameter each with 48 inches stroke of piston and connected to a crank at one end of the fly-wheel shaft. The surface condenser was the Wheeler independent form with independent circulating and air-pump, the station being near an arm of the sea. The fly-wheel was 20 feet in diameter with 40 inches face, and was said to weigh 38,000 pounds. It was belted directly to a jack-pulley on a shaft near the center of the building, a little way in front of the cylinders. The passage in front of the cylinders was under the slack side of the belt and over the tight side which ran underneath the floor at that point. The jack-shaft was continued by several lengths of line shafting connected by friction clutches and carried pulleys belting directly to the dynamos. The accident occurred in October, 1890, in connection with a small fire in the tower of the building from which the conductors for arc lamps were carried out to the pole lines. The nature of the destruction was very similar to that which occurred at Manchester, a swath being cut through the roof and both sides of the building, and at least one piece of the fly-wheel was carried fully 150 feet horizontally across a vacant lot and a railroad track, wrecking the corner of a house and falling alongside the cabin of the watchman at the railroad crossing. Fortunately no deaths resulted from this accident, though two men were temporarily injured by flying pieces. Interest in the case has been renewed by a suit brought by the electric company against the insurance companies for reimbursement for all the damages that occurred, not only from the fire directly but those due to the wrecking of the engine. In connection with Mr. Manning, of the Amoskeag Mills previously mentioned, and Mr. C. J. H. Woodbury, vice-president of the Boston Manufacturers' Mutual Fire Insurance Company, the writer was engaged as an expert by the insurance companies. It is thought that it will be of interest to briefly state the points claimed by each side in this very interesting litigation, for the reason that all

were dependent on electrical mechanical engineering principles combined in an unusual way.

The insurance law in Massachusetts is understood to be that insurance companies are responsible not only for the fire but for all damages directly occasioned by the fire. The burden of proof is, however, on the insured to show that the losses other than those from the fire itself were actually occasioned by the fire. The plaintiffs in this case did not, therefore, attempt to account for the fire in the first instance, but endeavored to show that such fire caused all the damage; they claim that the fire caused a short circuit in the tower by enveloping the plates of the fire arresters in flame and possibly expanding them so that they came in contact. They claimed that this short circuit was brought on so suddenly that it broke the pulley operating the dynamos then in use, that pieces of this pulley flew and hit others, and, according to one phase of the theory, one of the pieces broke off one ball of the governor so that the engine ran away and caused the damage, and according to another phase, providing for the fact that the loss of one ball would not disable the governor, it was assumed that the jar due to breaking the first pulley caused the next pulley to break, and that the next, and so on from pulley to pulley across several undisturbed bearings and a friction clutch attachment, a distance of about 30 feet, until the jack-pulley was thus broken, and that then pieces of this were carried by the belt under the fly-wheel and broke that, causing the wreck.

On the part of the defendants it was only necessary to disprove the probability of the assumptions, but in addition affirmative proof was presented to show that the conditions indicated a defect in the governor belt and that the damage to the machinery was simply due to the running away of the engine. The disaster occurred between 1.30 and 2.00 A.M. when current was being supplied for only 95 arc lights and for incandescent lights in the station. The arc lights were operated by two 50-light Thomson-Houston dynamos, such lights being distributed in four circuits from the station, which were, however, coupled two and two in series so as to form one circuit for each machine. Both dynamos were operated by one pulley on the line shaft, the belt to the pulley of the farther dynamo running over the driving pulley on the top of the belt from the other dynamo. A similar pair of dynamos were running on open circuit at the time, and in addition an alternating dynamo and exciter for the same were in operation to light the station. There were at the time only two men in the engine- and dynamo-room and a third man in the fire-room adjoining. The testimony of all was to the effect that one discovered the fire in the tower, and that another who was busy wiping shafting came and inspected it. The statements were to the effect that up to that time everything was working smoothly. It was stated that one called out to the firemen to blow the whistle, and then turned on the fire-alarm near another entrance to the building, and that the watchman, after inspecting the fire, went to the throttle-valve of the engine. It was claimed that suddenly there was a tremendous roar indicating a short circuit. The evidence of the fireman would imply that the roar continued for some time, but the testimony of the engineer was to the effect that coincidently therewith the pulley driving the two dynamos went to pieces and that immediately other pulleys commenced to fly and that he left the building. The watchman claimed that he had started to shut steam off the engine, for a reason not clearly explained, but that the pulleys commenced to fly and he, though struck by a flying fragment, bounded over a gate out of another exit.

All the experts agreed that the first effect of short circuiting a Thomson-Houston arc dynamo is to materially increase the load, due to the increase of current, but that such load is very soon brought back to the normal by the action of the current regulator. The efforts of the plaintiffs were to show that the short circuit, being an electrical phenomena, brought an instantaneous shock on the dynamo, which was transmitted through the belts from the dynamos to the operating pulley on the main shaft. Instances were cited showing that a belt operating a dynamo had in several cases been run off in this way, and in

one instance the belt became foul with the operating pulley in such a way as to crush it. An important point arose as to the time it required the dynamo regulator to act and reduce the current; several of the witnesses claiming that it required ten to fifteen seconds, and all agreeing that this time would vary with the condition of the apparatus and the amount of damping afforded by the fluid in the cylinder attached to the regulator. As a method of accounting for the short circuiting, the plaintiffs presented a diagram of the lightning arresters in the tower. There was one connected in each outgoing and each incoming conductor of each circuit, and as there were four circuits in use there were, therefore, eight lightning arresters involved. The four circuits were, however, as stated, coupled up at the time to make two, one for each machine; that is, the current going out from one terminal of the dynamo came back to the switch-board instead of to the dynamo and was directed out on another circuit and brought back to the dynamo through the second terminal of the second circuit. To account for the short circuiting it was claimed that the fire filled the whole tower with flame, which, as it contains carbon, was a conductor and short circuited the dynamos by enveloping the segments of the lightning arresters. It was also claimed that in due time such segments became sufficiently expanded by heat to be brought in actual contact and thereby make a metallic short circuit. It was further claimed that fragments of carbon from the burning woodwork dropped between the horns of lightning arresters and thus short circuited them, and that in one or more of these several ways the several lightning arresters were connected to form a short circuit. In response, the defendants urged the improbability of any such action. Such a short circuit could only take place by grounding both branches of each circuit through two lightning arresters at the same time. The fire was localized in the vicininy of two of the arresters which were on the same circuit, but such circuit was connected in series with another, so that if short circuited it would only cut out about half the lights in the double circuit, or one-fourth of the whole. Two other lightning arresters of the four circuits were near and two more were on the opposite side of the tower where there were few signs of fire. It was clearly shown that to short circuit all the lights through the lightning arresters the segments of at least four widely separated must be in contact or the space bridged by flame or dropping sparks at exactly the same instant, and if this were done by flame it was necessary that the flames, which would naturally roll around and show alternately flame and smoke as in any fire, should form forks of conducting flame sufficient to form a short circuit at four to eight different points in the tower at exactly the same instant, Any less mysterious coincidence would only short circuit one pair of lightning arresters and cut out about half the lights on one dynamo, or roughly one-quarter of the whole, and if this operation were repeated shortly after, another quarter would follow, and so on, and instead of a sudden shock it would be a series of small shocks quite insufficient, even on the theory of the plaintiffs, to cause the damage. It was shown that the quadrants of the lightning arresters would be expanded at a temperature of 1200° sufficient to be brought in contact, but it was difficult to suppose that the flame was at a sufficiently high temperature to expand all at the same time when the fire was confined to one corner of the tower. Ordinary flame has a temperature, according to the books, of 790° for the reason that currents of air are commingled with it in order to carry on the combustion with a material developing so much hydro-carbon gas in the process of combustion. Brass melts at about 1950° and it is well known that brass cannot be melted in an ordinary wood fire, but requires a blast with charcoal or other solid combustible. The brass was not melted, so the highest temperature obtained in the hottest corner of the tower was therefore less than 1950° and much less elsewhere. It was further claimed on the part of the defendants that the fracture of one pulley would not necessarily fracture the next one on the line, and that of the next and so on, and produce the train of

breakages in the order claimed by the plaintiffs. The plaintiffs showed that one of the piers of the line-shaft alongside the first pulley that broke was fractured, and claimed that this was done by that pulley fouling at the time of the short circuit, bringing a jar on the pillow-block, which caused the disruption of the next pulley and that in turn the next, but this was answered by the fact that no other pier was injured and that no great shock could be transmitted beyond the next journal. There were two journals before reaching the two on either side of the jack-pulley, neither one of the four being disturbed, and a friction-clutch intervened. The defendants claimed that the pieces of the first pulley which it was in testimony flew up and struck the ceiling and the switch-board could not in the limited height available spread very greatly, and that therefore no piece of the first pulley could fly off at an angle of 40° to 45° for a distance of about 40 feet and break the governor of the engine at the outset, and it was stated that if it did the engine would still be under control.

It is possible that failure of a pulley or fly-wheel may commence nearer one edge than the other and thereby tend slightly to disperse the pieces, but the breakage entirely across the face would follow so nearly at the same instant that the component of the force due to the velocity in the plane of the wheel would be much the greater, and only such of the flying particles as flew high in the air could disperse laterally any considerable distance. Any piece that was thrown straight up after the roof or other obstructions had been removed would, at velocity of 19,235 feet per second, rise to a height of nearly 1600 feet or, say, over 1000 feet allowing for the resistance of the air, and such piece in falling, if diverted to the slightest extent, might reach to a considerable distance laterally, though such a result would be prevented by obstructions in a building. One of the most interesting experiences during the bombardment of Forts Jackson and St. Philip, on the Mississippi river, during the war, by the Porter bomb fleet, as told by soldiers of the Southern army afterward, was the way in which the pieces of shell scattered. In most cases the shells coming down vertically buried themselves in the mud and merely threw up a large volume of it, causing a general scattering of the groups of soldiers for the moment and a laugh afterward. Sometimes men playing at cards would run like mice to the casemates and avoid the direct result of an explosion and then be back as quickly to their positions in the game, and on several occasions after they had all returned and were laughing over the last Yankee shot and noting the discomfiture of some one who was covered with mud, they would be startled by a sudded whirr and the "lazy piece," as it was called, would come back from the skies and perhaps injure one or more of them. The "lazy piece" meant one thrown vertically upward at the time of the explosion and which, therefore, being unobstructed, rose to a great height and took considerable time to rise and return.

It was also claimed by defendants that if the jack-pulley broke before the main fly-wheel and pieces of the former were carried on the belt underneath the latter, the upward strain would not necessarily break the fly-wheel, or at least not without breaking the frame of the engine or the pillow-blocks, cap or bolts, which was not the case. The plaintiffs showed that the frame of the engine had been racked, but this the defendants accounted for by the shaking of the engine on its bed when running away.

The defendants, the insurance companies, after answering the theories of the plaintiff, claimed that the whole accident was caused by the running away of the engine, due to the slackness of the governor belt or the slipping out of the lacings, whereby the governor acted rather slowly or entirely ceased to act. No safety attachment was provided for such an emergency, but the engineers have applied one since the accident. As to the cause of the fire, it only required a little moisture on the wood of the tower to which the lightning arresters were screwed to cause a slight leakage between the terminals of the dynamo when a very moderate increase of electro-motive force would cause additional current to cross the shunt formed by this leakage and char the wood so that it would become a good conductor

and thus form a short circuit, which, though only throwing out, say, one-fourth the lights, would start the wood-work in a blaze and cause the slight damage by fire in the tower, which apparently cost only about one hundred dollars to repair.

It was in evidence that the governor belt was new, though this was denied by the engineer in charge. An engine controlled through a governor belt with the lacing coming out would accelerate speed quite rapidly, and the speaker claimed that if the current regulator of dynamos required ten to fifteen seconds after a short circuit to control the current as claimed by plaintiffs' experts, it would also fail to promptly control the current due to a rapid increase of voltage from rapid acceleration of the speed of the engine and dynamo and cause a short circuit and the fire, and that at any rate it was doubtful if the regulator could control the current within unusual limits such as would obtain if the speed of dynamo were doubled, or much less if it raised from 850 to over 3000 revolutions per minute, as would have been the case if the engine ran away. In answering this the Thomson Houston expert made another close distinction, as he claimed that though the regulator was slow in checking an electrical phenomenon like a short circuit, still, being itself operated by electricity, it really changed at a faster rate than it was possible to cause a mechanical change, such as an acceleration of the engines. This by no means follows, as it will be shown that the engine would quadruple its speed and that of the dynamos in seventy seconds or less, according to the work being done. The Thomson-Houston expert, however, acknowledged that it was doubtful if the regulator would control the current when the speed of dynamo increased to more than 1700 revolutions per minute. The insurance companies also put in the evidence of an electrician that one of the station transformers was burned out, indicating increased speed of the alternater and exciter, but the other side denied this. The plaintiffs put in testimony that any increase of speed would have been noticed at the start, but evidently men occupied with a fire might not observe it. The roaring noise heard by the fireman could not have been that due to a short circuit which instantaneously caused the break on the theory of the plaintiffs, as the noise and the breakage were, according to such theory, coincident and over in an instant. A man who was called from the fireroom, therefore, could not have heard the roar, so-called, of a short circuit before the breakage occurred. He could, however, have heard the increased buzz due to the more rapid passage of the gaps between the commutator segments under the brushes. The defendants naturally suggested that the men did observe that the engine was running away, and that the watchman went to the throttle-valve for that reason and commenced closing it, but by that time the speed was so great that the pulleys of largest diameter on line shaft were being disrupted by centrifugal force, and it is probable that the one driving the dynamos being slightly distorted by regular strain was the first one to go and that the others of same diameter on the line shaft followed in succession. The acceleration of speed once started could not be controlled by the governor belt, so the speed increased until the main fly-wheel was disrupted by centrifugal force, breaking the jack-pulley, throwing down the roof of the building, and cutting a gap in the roof and sides.

The plaintiffs claim that if the speed of the alternater and exciter increased, the lamps would have been brighter, but evidently the men would not have noticed this if occupied with the fire. They also claimed that since the rim speed of the armatures was greater than that of the pulleys they should have been disrupted first, which was answered by the statement that the materials of the armatures were of higher tensile strength. In fact, the globular shape of the armatures of the arc light T. & H. machines is well adapted to prevent any injury to the winding by centrifugal force, and the wrought-iron cores of the spools in the alternater were evidently able to resist much more speed than any cast-iron construction. Tests were made by the plaintiffs to find if a governor like that on this engine would regulate with one ball in use. The sleeve lifted by a governor

of this size was quite heavy, so it was found that the speed of engine under such circumstances would have been increased to about 118 revolutions per minute, but even this was well within the safe limit even of the pulleys with the most rapid rim speeds.

The speaker made calculations to determine the speed at which the engine and several pulleys would be disrupted by centrifugal force. The normal speed of the rim of the fly-wheel at the diameter of the approximate radius of gyration was 4715 feet, or $\frac{9}{10}$ of a mile per minute. The rim speed of the jack-pulley must therefore have been substantially the same, or a trifle less on account of slip, and the rim speed of the 6-foot pulleys on the shaft operating the dynamos as well as the rim speed of the pulleys of the dynamos themselves have been about 50 per cent. greater than that of the fly-wheel. From the formula above given it was calculated that for a tensile strength of 10,000 pounds per square inch the fly-wheel should have been disrupted at 310¼ revolutions per minute, or, roughly, four times the normal speed. The 6-foot pulleys on the jack-shaft should, however, have been disrupted when the engine was running at a speed of 207 revolutions per minute. In order to ascertain approximately the time it would require for an engine under these conditions to run to destruction in case the governor belt were entirely disabled, it was assumed that even with the increased draft on steam-pipe, due to running away, a mean pressure of 48 pounds would be obtained, referred to the large cylinder. By "referred" we mean simply that the mean pressure in the small cylinder, divided by the ratio of the area of the two cylinders, is added to the actual pressure in the large cylinder. This mean pressure was sufficient to give 900 horse power at a normal speed, and of course the power increased with the speed. It was, however, considered that 13.5 pounds mean pressure out of the 48 were required until the first pulley broke to operate the dynamos and shafting, this pressure being sufficient to produce 253 horse power at normal speed, which is probably a liberal allowance. The mean pressure of 48 pounds is also well within limits, at least for the initial increase of speed, so the time stated hereafter as required to destroy the wheel is probably somewhat greater than would be the case in practice. To ascertain such time it was considered that not only the fly-wheel but every pulley connected therewith, as well as the armatures of the dynamos, really formed fly-wheels which would require force either to accelerate or retard their velocity. To ascertain the effect on the result, the revolving weights of each were ascertained or estimated and multiplied by the ratio of the speed of same to that of the fly-wheel. The sum of these quantities showed the additional weight which it would require in the fly-wheel rim to produce the same result. It was found that the aggregate result was the same as if 10,120 pounds had been added to the fly-wheel rim, making it weigh practically 48,000 pounds instead of 38,000. On this basis it was calculated that it would require 45 seconds for the engine to increase its speed from 76 revolutions to 207 revolutions, when, on the basis of 10,000 tensile strength, the pulleys on the line-shaft should have been disrupted, and as the disruption of such pulleys would have reduced the load on the engine, with the exception of friction, it would only have required 27 seconds, or in round numbers 1½ minutes from the beginning, to raise the speed to 310¼ revolutions per minute and disrupt the fly-wheel. There was testimony in the case to the effect that the engineer on watch confessed to his brother engineer that when the fire in the tower was discovered he pulled the plugs cutting out the arc lights and thus released the load on the dynamos. With this state of facts the load on the engine would have been released earlier and the time required to run to destruction have been diminished. If, however, the governor belt was not broken, but simply slack, so that it took care of changes of load slowly, the acceleration could have progressed at a much less rapid rate.

From what has been stated it will be seen that the combined mechanical and electrical conditions involved in an accident to an electric-light plant involve even greater refinements and complica-

tions in tracing cause and effect than has heretofore been the case with simple mechanical questions. It will also be observed that a very important question of principle arises in relation to damages occurring in connection with a fire, but not actually caused by the action of the fire itself. It has become necessary in many of the States by law and judicial decisions to exclude what are called "consequential damages," particularly in relation to public works, and this was founded on precedents long established in the old countries. For instance, under the common law a man in digging on his own land was not responsible for damages to a building on adjoining property. It is well understood that a man who fails to pay a debt is only liable for the amount of the debt and interest, although his delay may have caused failures which injured many other persons. So, also, in case of accident, or in fact of any injurious change of condition, there is always a direct result followed by others more or less indirect also in the nature of damage. The indirect results are so far-reaching, a damage to one causing more or less injury to another, that litigation would never cease unless some legal estoppel were put upon it, as has been done in relation to many kinds of transactions. Evidently, occurrences of a kind like that in the electric-light station will have the effect of causing some such limitation in regard to insurance. If a fire which caused a direct damage of only $100, by fire, and immediate injury to only a few hundred dollars of fixtures in the neighborhood, can in addition be charged with the cost of injuries caused by a runaway engine, there might conditions arise where still further consequential damages would go on almost without end. For instance, questions of personal injury might be involved from many people struck by flying fragments, or a large fragment might knock down a draw-bridge in the vicinity and wreck a train of cars, or such a fragment might strike a vessel loaded with explosives and cause a gunpowder or a dynamite explosion which would wreck the whole neighborhood, and if such explosives were required for use by a then friendly government and that government failed to prevail in an impending war for a lack of such material, the one hundred dollar fire in the beginning might cause international complications and result in a general war. Somewhere in the progress from first cause to final effect the law of consequential damages should, and will sooner or later, be made to apply, and special policies will be written when accidents to machinery are to be included. Without anticipating what will be done, it would seem natural to limit the damage at a point where the carelessness of the employees or of the insured, by defects in mechanism or material, caused the increased damage. In the case under discussion the judge ruled, for the purposes of the trial, that, even if the pulley was defective which it was claimed broke first, so that it broke with less strain than such pulleys should, still the insurance companies would be liable. Evidently if this were the case any slight accident, such as short circuiting the electric lights outside but near the station, or the dropping of a tool in some part of the machinery, might *without fire* have caused the other more important damages. It therefore appears equitable that at such a break in the chain as this a limitation of damage arising from fire should be made, on the general principles that have made it necessary to provide limitations in other cases, and also on a principle like that of contributory negligence in case of personal injury, whereby it would be provided that whenever the insured were themselves also at fault, either through the action of their employees or by the use of defective machinery, which would be liable to cause such accident without fire, the damage from fire should be limited at that point. Who knows but what the courts may finally hold that this is a fair interpretation of the law as it stands?

VENTILATION OF ENGINE AND BOILER ROOMS.

By Alfred R. Wolff, M.E.



THE proper ventilation of engine and boiler rooms, though usually neglected, is a matter of great importance. The heat generated in these rooms from the combustion of the fuel, from the radiation of the furnaces, boilers, steam pipes, heaters, engines and dynamos, is intense. Furthermore, there is a smell of oil, and of escaping vapors of steam and of paint under high temperature. The detrimental effect of these conditions is felt in various ways. Heat and noxious vapors are transmitted to rooms adjoining and above the boiler and engine rooms, and are offensive to the occupants of the building. Frequently ducts which are presumed to transmit cold air to other rooms in the building pass through the engine and boiler rooms and thus the air is heated in transit, and enters these rooms warm, instead of cold as desired, and the beneficial effect is lost. Again, in electric plants, the dynamos become inefficient when the temperature of the room is excessive. Lastly, and not least, the engineer force suffers exceedingly, which is not only annoying and detrimental to health, but results in less efficient handling of the plant, for men cannot do their best work and look out for their employer's interests under conditions which cause them physical and mental discomfort.

Any proper system of ventilation of boiler and engine rooms, especially if the rooms are located in cellars of large buildings, requires the bringing in of fresh air to dilute and cool the atmosphere in the rooms, and requires, at the same time, the exhaust of air from these rooms. Either system alone will not answer. If air is supplied under pressure and no proper exhaust provided, it is true the room will be somewhat cooled and freshened, but the still heated air and noxious vapors will be distributed with greater force to the rest of the building. If an exhaust system alone is used, and it is sufficiently powerful, the heat and the noxious vapors will be partially removed and will certainly not distribute elsewhere than in the room, but the air which will be drawn into the boiler and engine rooms will not necessarily be pure air and certainly not cold air, and thus the temperature of the room will not be sufficiently lowered, and the air not be fresh enough. If one system alone is to be used, the exhaust is the best, but neither system alone really meets the need.

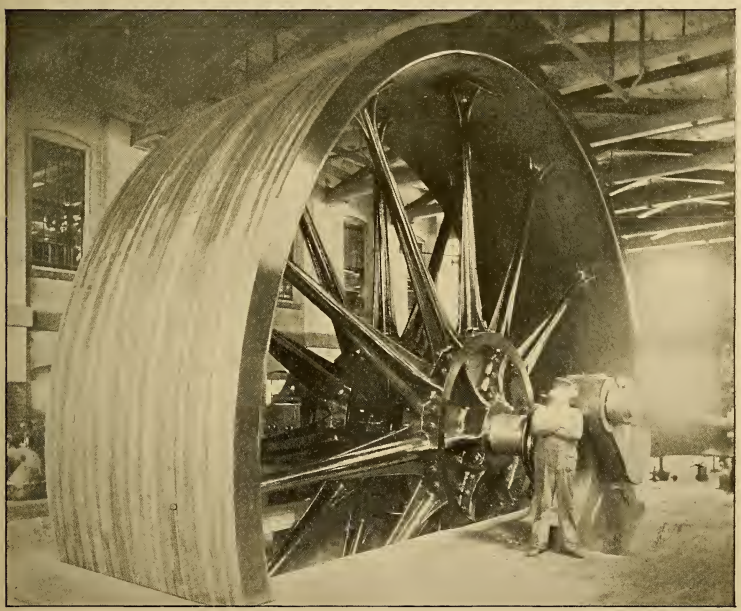
The most satisfactory way of bringing in the air is to distribute it by means of galvanized iron ducts to various portions of the room, not as is frequently practiced, by having one large inlet at one end of the room. These galvanized iron ducts should have outlets at those places where the men are principally at work, for instance, near the engine cylinders, near the dynamos, near the furnaces, and preferably, the horizontal transmitting ducts being near the ceiling, there should be funnels with registers or dampers led to a height just above the men's heads. The transmitting fresh-air ducts in the engine and boiler rooms should be well covered with non-conducting material, for it is essential, especially in the summer time, that the air which enters the boiler and engine rooms be pure air from without, and not of higher temperature than the external atmosphere. To create a proper circulation, the exhaust system from the boiler and engine rooms should also be arranged with corresponding outlets at the various parts of the room, these outlets connected by galvanized iron ducts with the main exhaust flue. Thus is insured a circulation and distribution of air to all parts of the room. The galvanized iron vent-ducts do not, of course, need to be covered with non-conducting material. All the inlets and outlets should have their separate shut-off registers or dampers, so as to be easily under control of the engineer.

There can be no better investment for the owner of a steam and electric plant than to have the engine and boiler rooms properly ventilated. The first cost of such an institution will bear him a handsome return in the smooth running of the plant, a greater fuel economy, in the increased comfort of the tenants and the greater welfare of his employees.

A WOODEN RIMMED FLY-WHEEL.

AFTER the accident to the great fly-wheel at the mills of the Amoskeag Manufacturing Company at Manchester, N. H., the chief engineer of the works, Mr. Charles H. Manning, began to construct a wheel to replace the bursted one. This wheel, an illustration of which is shown on this page, is of interest for the reason that it is probably the first great fly-wheel constructed so largely of wood.

The wheel is 30 inches in diameter, 108¼ inches face, and the rim of Western ash is 12 inches thick. There are two cast-iron hubs put on in halves, as he did not wish to remove either crank. The joints of the two hubs stand at right angles to each other and the key-way half-way between them. Each hub carries twelve arms, the hubs turned and the arms forced to fit, and their bases making a complete circle about the hub



WOODEN RIMMED FLY-WHEEL. DESIGNED BY CHARLES H. MANNING.

and each arm bolted to hub with four 1¾, inch iron bolts. The arms are hollow, cylindrical in sections, taper, and to

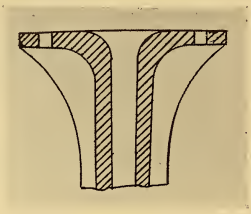


FIG. 1.

avoid shrinkage strains the cross-section (radial) is constructed as shown in Fig. 1. There are four ribs on the outside running well out, and four others at the outer end. The outer end is spread into a foot about 20 inches square and there are eight bolts on each arm, the heads being set with the rim and the holes plugged.

The stock used was the best kiln-dried Western ash, 3 x 4 inches, which was dressed down to 3½ x 2½ inches, besides which there were a few circles of 1½-inch stock.

The total number of rings were forty-two, each ring being made of twelve pieces of equal length, the joints being carefully broken. Each section is glued and fastened to the preceding one with sixteen long bolts of appropriate length, making nearly seventy-five hundred long bolts in the rim. The ends are left open about three-fourths of an inch on the outside, and one of the best operations was to drive keys into each of these openings.

Keys are also driven under the ends of the arms as shown, Fig. 2. The immense amount of boring, as well as of setting up the long bolts, was done by power with flexible shafts. Between each two arms are three ⅞-inch iron bolts extending through the rim from side to side. When all together the pulley was turned in place for two 51-inch belts.

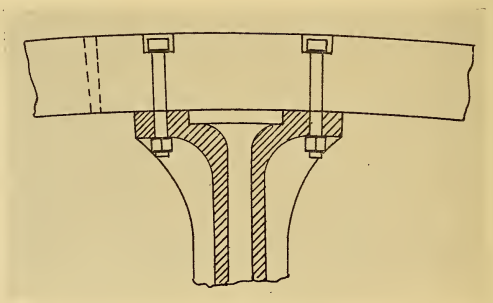


FIG. 2.

The weight is something over 100,000 pounds, and the cost was less than the original cast-iron pulley which went to pieces.



AUTOMATIC SPRINKLERS.—II.

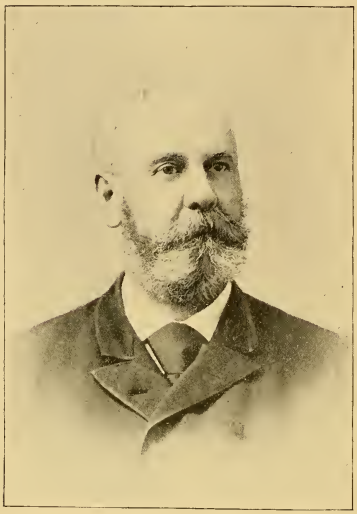
By C. J. H. Woodbury, Vice-President Boston Manufacturers' Mutual Fire Insurance Company.

ALTHOUGH the fundamental principles of the apparatus designed for the automatic extinction of fires is entirely English in its origin, yet the surmounting of the numerous practical details essential for the solution of the problems involved in the construction of an automatic sprinkler which would resist all the conditions tending to impair its efficiency, and at the same time always be ready for service when exposed to the proper degree of temperature, is entirely the work of American inventors.

And the greater work has been required in overcoming the natural doubts and prejudices of those who properly questioned the ability of such apparatus to fulfill all the hopes of enthusiastic inventors and in implanting confidence among the great number of men whose possessions were invested in manufactories, as well as the underwriters who in like manner shared in the liability of fire-loss which would be abated by such apparatus if successful, but in case of failure this new apparatus would have proven indeed a broken reed.

Charles E. Buell, who is a prolific inventor in other lines of mechanics, has also been one of the pioneers in inventions upon automatic sprinklers. Passing by some of his earlier devices, his present sprinkler contains a thin plate of mica upon the valve-seat to prevent adhesion. The valve is pressed against the seat by a spring-plate of phosphor bronze, and the soldered joint at the

bottom is placed between two pieces of brass containing numerous V-shaped corrugations, which fit into each other in such a manner as to relieve the solder from shearing stresses.



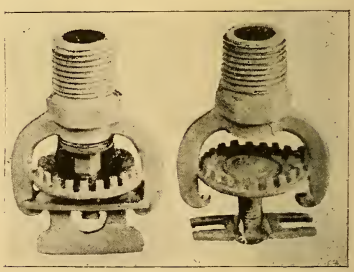
Charles E. Ruud.

Almon M. Granger, of Buffalo, was among the early inventors of automatic sprinklers. His devices contained many features which have been important contributions to the art of automatic extinction of fires.

While all are agreed that an automatic sprinkler should distribute water uniformly against the ceiling above and the floor below, without any omissions throughout the range of its service, there are legitimate differences of opinion as to whether the most efficient results are reached by dividing the water into a fine spray or by retaining its mass in fine streams as far as possible. The automatic sprinkler invented by John Hill, of Columbus, Ga., is the most perfect exemplification of the latter theory. The deflector is folded to an upward curve on one side, and downward on the opposite side with gradual changes from one to the other. It is mounted on a spindle held in a step at the lower end and surrounded at the top by the chamber at the outlet of the sprinkler.

The water flows over the deflector in a continuous sheet, but it also causes it to revolve in an oscillating motion similar to a dying top, and changes the course of these streams of water in all directions very rapidly. The valve-seat is protected against adhesion by a grease derived from mineral oils. The soldered joint consists of two semicircular pieces resting upon a circular and slightly curved piece of thin spring phosphor-bronze ; a countersink in the center of the top pieces forms the step for the spindle which holds the deflector. The solder is peculiar to this sprinkler, and has a very low fusion-point. This sprinkler is very sensitive, and has done excellent service at a large number of fires,—the average insurance claims on such fires being very low.

The sprinkler invented by William Kane, of Philadelphia, is constructed on the theory that the best results are obtained when water is divided into a very fine spray. The water issuing from an



BUELL AUTOMATIC SPRINKLER.

opened sprinkler impinges upon a wheel, which is a propeller with six blades, and causes it to revolve with great rapidity, producing a spray which issues uniformly in all directions.

The valve is held to its seat by a single lever held by a detachable link, made of two pieces of brass with trans-

verse corrugations at the solder-joint. This sprinkler is extensively used in the manufacturing districts in Eastern Pennsylvania, and has made an excellent record at numerous fires in textile mills.

William Neracher, of Cleveland, has invented a sprinkler in which the valve is held to its seat by a pair of toggle-joints secured by a triangular link at the bottom of the sprinkler. The various pieces forming the toggle-joint are terminated in knife-edges, without pins or surface connections to be fixed by corrosion. The deflector is a flat cone with numerous protuberances.

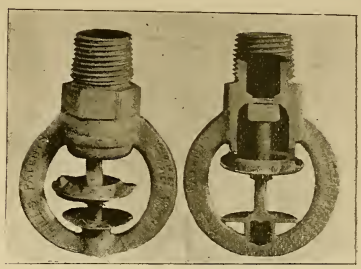
The proverbial Yankee ingenuity does not appear to have exercised itself on the subject of automatic sprinklers at the reputed center of that branch of the nation, for there is only one auto-



John Hill.

matic sprinkler which comes from Boston, but it may claim to possess all the possible merits which might have been included in any half-dozen automatic sprinklers which might have been invented in that city.

C. C. Walworth and Osborn B. Hall



HILL AUTOMATIC SPRINKLER.

jointly invented the automatic sprinkler known as the Walworth sprinkler, and first patented October 23, 1883.

The deflector is stationary, and the valve is held to its seat by a bell-crank secured at its upper end by two links, each made by bending a strip of sheet-brass, about a quarter of an inch in width, to the form of a U, each piece being of the same size; they are soldered on opposite sides, and are therefore free to break away when heated without sliding the soldered surfaces along each other.

The outer link fits loosely and is soldered with an alloy of very low melting-point, and will open first, so that the inner link is perfectly free to open an instant later. The inventors of this sprinkler admit that two smooth surfaces joined by this solder are more liable to yield under the impact of extreme pressure and water-hammer, but claim that such joints are more prompt to act when heated, and therefore avail themselves of the one advantage and avoid the other possible difficulty by the use of the second outer link, which holds the sprinkler in case the inner link extends. If such a mishap should occur, which is very rare indeed, the outer link will hold the sprinkler from opening, and the occurrence would be revealed by fine streams issuing from the sprinkler. It should not be assumed that such mishaps are at all likely, but the device is in the nature of a pre-

caution against a possible contingency under some conditions of water-pressure. The valve of the Walworth sprinkler is prevented from embedding into the lead



William Kane

seat by means of a gasket of thin copper, for the purpose of preventing adhesion of the valve to its seat. The use of cast-brass in the construction of automatic sprinklers is an advantage over rolled or spun-brass on account of its higher resistance to corrosion.

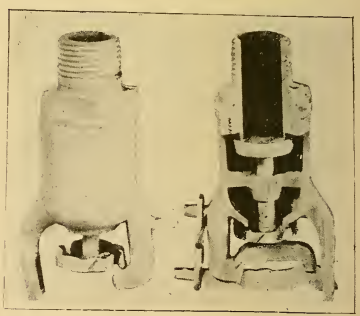
The Walworth sprinkler has been extensively introduced in manufactories throughout the United States, and has a record of prompt operation at a great number of fires.

Joseph Clapp, of Chicago, invented an automatic sprinkler containing several extremely desirable features in regard to simplicity of form and also resistance to leakage and corrosion. Phosphor-bronze is used for the construction of the sprinkler on account of its strength and resistance to corrosion. The valve is covered with a vulcanized fiber disc to protect against adhesion. The valve is held in place by a strut made of three pieces of phosphor-bronze soldered at their edges and protected against corrosion by a thin sheet of phosphor-bronze soldered to each side of this strut. This sprinkler is free from exposed rubbing surfaces, and the distribution is effected by a rotary deflector, which is also perforated.

The Manufacturers' automatic sprinkler is based on the original invention of the late John C. Mackey, with numerous improvements made by Robert Wood. It is one of the type of sprinklers in which the valve is held to its seat by a lever, and to resist corrosion the valve is made of a ball of porcelain.

The sprinkler invented by Captain W. H. Stratton, of Providence, is too recent a comer into the field of automatic fire protection to have a history, but it contains several features which appear to be of unusual merit, especially the precautions taken against its being disabled by corrosion. The valve-seat is a glass ring recessed on the inner edge to form a resting-place for the valve, which is composed of a concave piece of thin elastic metal.

In the sprinkler invented by Frank Gray the valve is held to its seat by a



KANE AUTOMATIC SPRINKLER.

perforated tube, which is secured at its lower end by an open thimble which is soldered in the tubular projection at the bottom of the deflector.

The references to automatic sprinklers have been entirely directed to their use for inside service, but they are not limited

to such work, as unsoldered sprinklers when placed under cornices have been of good service in protecting buildings against conflagrations.

Such fires always give warning of danger and afford an opportunity to turn on the water by hand. Automatic sprinklers are not entirely fitted for such use, because they are made to distribute the water in all directions rather than along the line of a cornice. The cornice sprinkler of J. P. Swan ejects water in a fan-shaped sheet for this purpose.

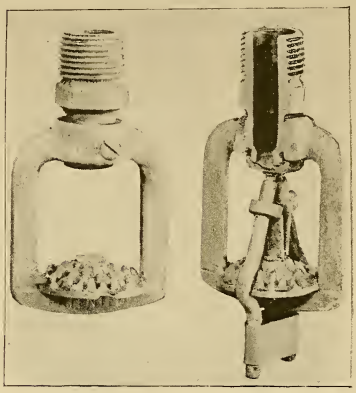
In the practical application of automatic sprinklers to the protection of property, the sprinkler-heads are merely a detail of a whole system of pipes and



H. Neracher

water-supply, every element of which requires careful design and constant espionage to maintain the apparatus in proper condition. The arrangement of pipes in an automatic sprinkler system follows in a general way the identical lines laid down by Major A. Stewart Harrison in 1864, but in their application to present materials of construction the numerous details require special modifications.

The standard schedule of sizes of sprinkler pipes is based upon experi-



NERACHER AUTOMATIC SPRINKLER.

ments by the writer on the discharge of automatic sprinklers, and the diameters of pipes are selected to give the nearest uniform loss of head by friction throughout the system when the sprinklers are each discharging a cubic foot of water per minute, or a head of about ten feet.

Nominal diam. of pipe, inches.	Number of sprinklers.	Loss by friction in feet-head.
¾	1	1.31
1	3	2.64
1¼	6	2.34
1½	10	2.7
2	18	2.8
2½	28	2.6
3	46	2.9
3½	70	3.1
4	95	4.1

Every automatic sprinkler system should be furnished with two sources of water-supply, one of which should rest on the sprinklers at all times, and the other preferably from a suitable fire-pump.

Check-valves opening toward the sprinklers, in the pipes leading from each source of supply, give to the sprinklers the advantage of the greater head of water without requiring any manipulation of valves. The following table of the

Factory Mutual Insurance Companies for the arrangement of automatic sprinkler pipes contains the results of the widest experience on the application of automatic sprinklers to buildings of different types of floor construction.

The terms "medium hazard" and "special hazard" relate to the contents or occupancy of each room.

"Specially hazardous places are such as picker-rooms, planing or sawing departments of wood-working establishments, painting- or varnishing-rooms, etc.

"Spaces directly over storage bins or racks, or immediately surrounding stairways, elevators, or large belt openings, should be considered under the rules for 'special hazard,' and deviation from a rectangular lay-out made, and extra sprinklers inserted, if necessary, to secure an effective distribution."

Enclosed machines devoted to processes involving unusual fire hazard, as rag-dusters and various forms of driers of textile materials, should have automatic sprinklers under the covers in such positions that they will be enabled

FOR STANDARD MILL CONSTRUCTION.

One row of automatic sprinklers in each bay placed midway between beams.

	With water-pressure at highest sprinkler.			
	Exceeding 20 lbs. per sq. inch.		Less than 20 lbs. per sq. inch or supplied primarily by tank.	
	Medium hazard.	Special hazard.	Medium hazard.	Special hazard.
In 12 ft. bays.	8 ft. apart.	7 ft. apart.	7 ft. apart.	6 ft. apart.
In 11 ft. "	9 ft. "	8 ft. "	8 ft. "	7 ft. "
In 10 ft. "	10 ft. "	9 ft. "	9 ft. "	8 ft. "
In 9 ft. "	11 ft. "	10 ft. "	10 ft. "	9 ft. "
In 8 ft. "	12 ft. "	11 ft. "	11 ft. "	10 ft. "
In 7 ft. "	12 ft. "	11 ft. "	11 ft. "	10 ft. "

FOR OPEN JOISTED CEILINGS.

Sprinklers should preferably be placed directly under a joist.

	With water-pressure at highest sprinkler.			
	Exceeding 20 lbs. per sq. inch.		Less than 20 lbs. per sq. inch or supplied primarily by tank.	
	Medium hazard.	Special hazard.	Medium hazard.	Special hazard.
At right angle to joists.	8 ft. apart.	7½ ft. apart.	7½ ft. apart.	6½ ft. apart.
Parallel with joists.	10 ft. "	9 ft. "	9 ft. "	8 ft. "

"In all cases the distance from wall to first sprinkler should not exceed one-half the distance between sprinklers in same direction.

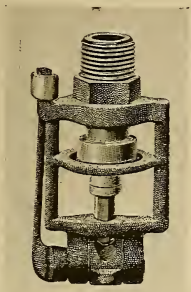
"The splash-plates of sprinklers should be at least 3 inches below joist or ceiling.

"In buildings having ceiling similar to standard mill construction, but with beams not exceeding 6 feet apart, center to center, a row of sprinklers under alternate beams is admissible, placed under centers of beams instead of midway between beams.

to apply water directly upon any fire originating in the machine. Sprinklers have in like manner been applied in trunks to cotton-pickers and chutes in flouring-mills, so as to be of service in case of fire occurring in such passageways.

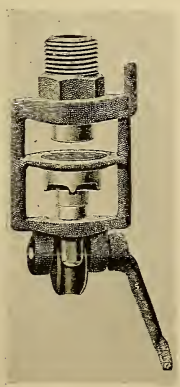
The limits of a magazine article prevent a reference, even by name, to numerous automatic sprinklers which show great ingenuity on the part of their inventors, but it has been the purpose of this article to illustrate the leading types of mechanism applied to auto-

matic sprinkler construction. The writer has a collection of about two hundred different automatic sprinklers, the work of nearly one hundred different persons. Most of these devices are absolutely unfit for the purpose for which they were



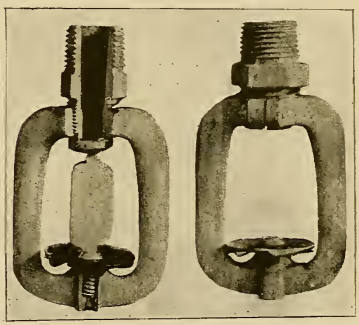
WALWORTH AUTOMATIC SPRINKLER. (CLOSED.)

made, the principal classes of defects being liability to leak or to adhere at the valve, solder-joint unable to resist water-pressure, or liable to be chilled by the water issuing from the sprinkler before it is fully open, liability to become



WALWORTH AUTOMATIC SPRINKLER. (OPEN.)

disabled by corrosion or by an accidental blow, poor distribution of water, or not sensitive to a slight heat. The experience of years has established the fact that a number of automatic sprinklers have been made on entirely different plans of construction, but which have in each instance avoided the defects mentioned above, and there is no reason to doubt but that a greater number of equally useful sprinklers may be produced in the future. Many ingenious inventors might have saved themselves from expense and disappointment if they had learned the nature of the sprinkler-solder, which is a weak, inelastic mixture, crawling by cold flow when in mass or thick films, breaking under slight elongation, needing special methods to secure close adhesion to other metals, especially to cast-brass, and requiring both skill and experience in compounding the solder. In short, it possesses the single requisite of low fusibility, reminding one of the remark that Satan has the single virtue of industry.



CLAPP AUTOMATIC SPRINKLER.

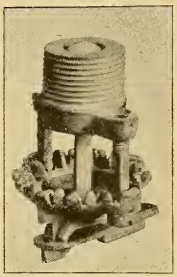
The solder has always failed by stretching and breaking whenever used in mass as links or bars, and Edward Atkinson, of Boston, was the first person* to make a link (June, 1878) composed of two pieces of brass soldered together with a film of fusible alloy.

The immediate application of this link was made in connection with hatches for elevators and with fire-proof doors and shutters, which would be closed by the heat of an approaching fire; but the same devices have been applied, with the necessary changes in dimensions, to

*Trans. New England Cotton Manufacturers' Association, vol. xxv, p. 41.

numerous forms of automatic sprinklers containing a removable link.

While many features of possible automatic sprinklers are common property, yet the elements and mechanical combinations of the automatic sprinklers in successful commercial use are most thoroughly protected by patents, and it



MANUFACTURERS' AUTOMATIC SPRINKLER.

will require invention in original lines to produce other automatic sprinklers which could be fully protected by strong patents.

The application of automatic sprinklers to practical use in the protection of property was made entirely through the factory mutual insurance companies, who write entirely upon isolated manufacturing property, and their experience has been so thoroughly established that the field for automatic sprinklers has been greatly enlarged.

The record of fires shared in by the largest of these companies for the fifteen years ending January 1, 1892, gives the following results, dividing the fires in two classes, the one being where automatic sprinklers formed a part of the apparatus in service at the beginning of the fire, and the other being the remainder of the fires extinguished by other apparatus, even including the numerous small fires dashed out by fire-pails without loss.

In the automatic sprinkler class there were 406 fires, followed by 206 claims, causing losses amounting to $247,673.38, or an average of $610.03 per fire, or an average claim of $1,202.29; and in the second class there were 1196 fires resulting in 501 claims to the amount of $8,720,437.98, making an average fire $7,291.33, and an average claim of $17,406.06. It will be seen by this that the average sprinkler fire amounts to $8\frac{3}{10}$ per cent. of the other fires, and the average sprinkler claim $6\frac{9}{10}$ per cent. of the other claims. These results can be applied by each one in his own manner, but in any event they will establish the fact that in their practical application automatic sprinklers are the greatest economic invention of the present generation.

It is no disparagement to automatic sprinklers to call attention to the fact that such protection has its limitations; they are applicable only in part to places not heated in freezing weather; they should receive constant inspection by all parties interested; they will never reduce incendiary hazard caused by scamps who know enough to shut off the water; they will not defend against the conflagration hazard; neither can they be relied upon to control any fires

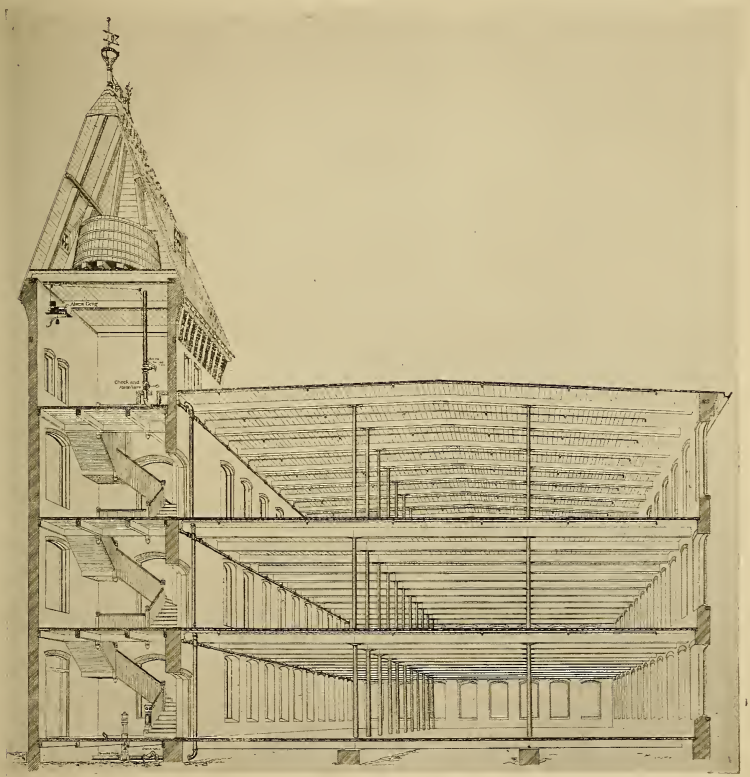


SWAN CORNICE SPRINKLER.

except those starting in rooms which they protect. They are not applicable in full measure to buildings containing large open spaces of great height, nor to those containing deep piles of combustible material. Like all other mechanical devices they are subject to

depreciation, which is particularly active in industries generating corrosive vapors or producing viscous products which adhere to the sprinklers.

The normal hazard of manufacturing establishments has greatly increased during the last ten years; buildings have been made larger, crowding into one structure a greater number of possible dangers; the speed of machinery has increased; the chemical changes due to more rapid dyeing and drying processes have increased the fires from spontaneous ignition of textile fibers; and the inevitable tendency of all these destructive conditions was leading to the most serious results to owner and underwriter, when the automatic sprinkler system, as an invention in due time, met these dangers in such potency as to reverse the conditions of greater hazard and diminish the fire-risk.



ARRANGEMENT OF SPRINKLER APPARATUS.

THE INJECTOR.—III.

By Professor R. C. Carpenter.

THE velocity in the suction can be found by considering a body of water with a head S, acting to accelerate or retard the whole mass of water in the injector. If water is delivered to the injector under a head, it would accelerate and be positive; if obtained by suction, it would retard the whole mass and be negative.

If we denote the number of pounds of water raised by one pound of steam by Y and the weight of steam by w, the total weight passing through the injector will be $(Y + 1)\,w$ pounds.

This may be substituted for $WV' \div g$ of equation (1), giving the form

$$\frac{V}{1 + Y} + \frac{S}{V} = V \quad (5)$$

The limit of suction-head, or the maximum distance which water can be raised by suction, will depend on the perfectness of the vacuum induced in the combining chamber and on the temperature of the feed-water. If the feed water gives off any sensible vapor, the distance which the water can be raised will be reduced accordingly.

TABLE II.

Temp. of feed-water. Degs. Fahr.	Pressure of vapor. Pounds per sq. inch.	Limit of suction-head in case of vacuum. Feet.	Steam pressure 100 pounds absolute.	
			Delivery 212° Fahr. No. of pounds of water to condense one of steam.	Delivery 180° Fahr. No. of pounds of water to condense one of steam.
70	0.36	32.96	7.04	8.81
80	0.50	32.6	7.57	9.61
90	0.69	32.2	8.19	10.76
100	0.94	31.4	8.92	12.11
110	1.26	30.9	9.80	13.84
120	1.68	29.7	10.87	16.15
130	2.22	27.3	12.20	19.32
140	2.87	25.9	13.89	24.22
150	3.70	24.8	16.13	32.3
160	4.72	22.5	19.23	48.45
170	5.98	19.6	23.81	96.90
180	7.50	16.9	31.25	.....
190	9.33	9.9	45.46	.....
200	11.52	9.3	83.33	.....
210	14.12	1.1	500 9	.....

Let a be the smallest section of the water jet, and w″ be the weight of a unit of water, then the pressure or force exerted by S feet of water will be S a w″. This force acts upon a mass of water moving with a velocity V through the orifice a, with a density w″, so that its mass would equal $V\,a\,w'' \div g$. The velocity imparted would be

$$S\,a\,w'' \div \frac{V\,a\,w''}{g} = \frac{Sg}{V} \quad (3)$$

The momentum imparted to $(1 + Y)$ pounds of water would be

$$\frac{(1 + Y)}{g}\,\frac{Sg}{V} = (1 + Y)\,\frac{S}{V} \quad (4)$$

Another important condition which must be fulfilled in order that the injector will work is that the supply of water must be sufficient to condense the steam, as the temperature of the supply or feed-water is higher, the amount of water required for condensing purposes will be greater. The above table gives the pressure of vapor from feed-water of different temperatures, also the amount of feed-water required to condense 1 pound of steam at 100 pounds absolute pressure, and the greatest possible suc-

NOTE.—Eq. 5 is readily obtained by substituting the value of Y (Eq. 11) after the substitution, as above.

tion-head for a perfect vacuum in the combining chamber.

The velocity v of the steam cannot be obtained by dividing the number of cubic feet of steam delivered by the least area of the orifice, because the exact pressure and quality of the steam at the instant of passing this orifice is unknown. Even if the pressure could be measured, the quality or per cent. of water would still be undetermined. As the volume diminishes rapidly with condensation, this is an important quantity.

In the case of the injector, the steam passes through a nozzle of varying cross-section, and there is little doubt but that as the area diminishes there is a certain loss of pressure, and corresponding increase of velocity, accompanied with a corresponding change in quality. Because of the impossibility of direct measurement it will be necessary to determine this velocity from the thermodynamical equations of flow, which take into account all the changes in pressure and quality. (See "Peabody's Thermodynamics," page 139.)

The solution of these equations regarding the flow of steam brings out some interesting facts, the first and most important of which is that the steam in flowing through an orifice in which the pressure on one side is much greater than on the other will reach a pressure which will give the maximum flow in pounds much before it reaches the minimum pressure. If the pressure were to fall more, the weight of steam discharged would be less, and if the pressure were to increase, the weight again discharged would be less; as the tendency is to discharge the greatest amount possible, it becomes at once evident that the pressure will only fall the amount necessary to give the maximum weight of discharge. This interesting fact is well brought out in the following table, computed by Mr. D. Royse and myself, which gives the velocity that steam would have in flowing from a vessel in which steam is maintained at a constant pressure of 100 pounds absolute through a nozzle in which the pressure is supposed to vary from 95 to .089 pounds absolute. The resulting velocity is seen to increase from 447 feet per second to very nearly ten times that amount, but the weight which is discharged is seen to be greatest when this pressure reduces to 61 pounds in the nozzle. For pressure lower or higher

TABLE FOR CALCULATED VELOCITY OF FLOW.

and corresponding weight of discharge from a vessel maintained at 100 pounds absolute pressure through nozzle subjected to different pressures. The pressure on the vessel receiving the steam must be less than in the nozzle.

Absolute pressure at least orifice. Pounds.	Velocity of steam at least orifice. Feet per second.	Proportional weight of discharge. Discharge through orifice one square ft. in area. Pounds per second.
95	447	97.9
90	650	125.2
85	806	159.2
80	940	175.4
75	1032	181.2
70	1182	194.5
65	1298	197.2
63	1345	198.3
62	1368	198.54
61	1390	198.91
60	1410	198 67
59	1430	198.34
55	1511	198.2
50	1612	193.4
45	1740	188.0
40	1858	185.2
35	1970	168.9
30	2116	156.1
25	2240	140.0
20	2420	131.7
15	2615	101.2
10	2860	74.4
5	3220	44.4
0.089	4420	....

than this the weight decreases, consequently we should expect that in the flow of steam from a higher to a lower pressure, no matter what the lower pressure may be, the pressure in the connecting-tube will be such as to give the maximum outflow, and will not be less

TABLE IV.

Steam pressure.		On orifice. Absolute.	Velocity of discharge. Ft. per sec.
Absolute.	Gage.		
100	87	60	1410
93 8	80	56.1	1408
83.0	70	49.8	1405
73.2	60	43.9	1401
61.1	50	37.8	1397
53.2	40	31.9	1389
43.2	30	25.9	1380
33.4	20	20.0	1372

than 61 per cent. of the greatest absolute pressure, and is independent of the pressure in the receiving vessel, provided that it be less than 61 per cent. of the greatest absolute pressure.

This theoretical calculation indicates

that the greatest possible reduction in pressure is 61 per cent. of the highest absolute pressure; on account of the action of the current of steam in inducing pressure or the contrary, the experimental determination is a difficult one to make. The following table is the actual results of an experiment made by Professor Peabody, and it is seen to agree well with the theoretical calculation.

Now, further than this, if the greatest reduction of pressure in the nozzle is to about 60 per cent. of the greatest absolute pressure, the velocity in the nozzle will change very little, as will be seen from the immediately previous table, calculated from the formula for the adiabatic flow of steam, on the supposition that the pressure in the nozzle is 60 per cent. of the greatest absolute pressure.

In the application of this result to the injector, it may be urged that the pressure at the point where the steam impinges on the water is less, and consequently the resulting velocity is higher; this view is in part true, but it is also true that the area of the injector tubes are correspondingly increased, which would reduce the velocity, so that it is probable that we have in this case the maximum velocity which the particles of steam have when they come in contact with the particles of water. This velocity slightly increases with higher steam pressures, but is very nearly constant, and practically 1400 feet per second. The density of steam increases with the pressure, so that the product of density and velocity will increase with the pressure; this product is the momentum, and measured the ability of the steam to overcome resistance, so we should find the capacity to do work to increase with the steam pressure.

Knowing the velocity of the steam, a simple calculation will suffice to determine the maximum amount of water that can be lifted against a given pressure. The method of calculation would be: the weight of steam multiplied by its velocity is equal at the limit to the product

TABLE III.

EXPERIMENTAL DETERMINATION OF PRESSURE IN NOZZLES.

Length of tube. Inches.	Pressure above atmosphere in pounds per sq. inch.			Ratio of absolute pressure in nozzle to that in delivery chamber.
	Delivery chamber. Pounds.	Receiving chamber. Pounds.	In nozzle. Pounds.	
1.5	72.5	12.7	40.3	0.631
1.5	72.4	14.7	40.3	0.631
1.5	72.4	19.6	40.4	0.633
1.5	72.2	24.6	40.7	0.640
1.5	72.3	29.3	41.0	0.64
1.5	72.3	34.5	41.8	0.649
1.5	72.5	40.0	44.6	0.680
average				0.636
0.5	72.4	13.6	38.6	0.612
0.5	73.9	15.6	39.4	0.613
0.5	72.2	20.0	38.8	0.616
0.5	72.4	25.2	39.0	0.616
0.5	72.5	29.7	39.4	0.621
0.5	72.1	34.8	39.7	0.628
average				0.617
0.25	72.4	27.1	36.1	0.584
0.25	72.4	27.9	36.1	0.584
0.25	72.6	28.7	36.3	0.585
0.25	73.3	29.6	36.7	0.585
0.25	74.0	30.1	37.1	0.584
0.25	73.5	32.3	37.0	0.587
0.25	71.3	33.8	36.1	0.591
0.25	72.7	35.5	37.0	0.594
average				0.586
0.25	124.3	26.9	67.5	0.592
0.25	127.3	31.0	69.3	0.592
0.25	125.3	34.8	68.4	0.594
0.25	127.6	40.6	70.2	0.596
0.25	128.1	46.9	70.3	0.596
0.25	125.9	49.5	69.3	0.597
0.25	125.9	54.1	69.5	0.598
0.25	126.0	57.5	69.5	0.598
0.25	126.3	60.0	69.7	0.599
0.25	126.5	64.7	70.2	0.601

of the velocity of the discharged water into the weight of water and steam delivered. Using 1400 feet per second as the most probable value of the velocity of the steam, we obtain the results in the following table as the maximum value of the ratio of water to steam, when delivery pressure is equal to that in the boiler, and the delivery temperature does not exceed 212° Fahr.

The Hancock inspirator and the Sellers 1876 form, after being started, will continue to work with the overflow-valve closed, and in this case there is strong evidence that condensation occurs under pressure, as the water may be discharged at a temperature greater than 212° Fahr. For this condition the maximum ratio of water to steam should be greater than that calculated. Table V, below, gives the calculated value of the maximum ratio of water to the steam, and the values obtained on actual trial.

TEMPERATURE OF THE FEED-WATER.

One of the most important practical questions relating to the injector is that regarding the temperature of the feed-water. As a boiler-feeder the question of water lifted per pound of steam is not of much importance, for the reason that all the steam used is returned to the boiler, but it often happens that warm water can be had by heating the feed-water with exhaust steam that otherwise would go to waste, and the ability of the injector to handle hot water becomes an important question and one seriously affecting the economy of the plant.

This can be obtained from the following equations :

The maximum ratio of water to steam that can be put into a boiler is given in

TABLE VI.

MAXIMUM TEMPERATURE OF FEED-WATER.

Gage pressure. Pounds per sq. inch.	Theoretical.		Experimental results.				
	Temp. discharge 180°.	Temp. discharge 212°.	Hancock inspirator.	Park injector.	Metropolitan.	Sellers. 1876.	Injector, old style.
10	.....	.....	.....	.....	.....	132	.....
15	.....	.....	.....	.....	.....	.....	.....
20	142°	173°	135°	120°	130	134	.....
25	137°	168°	.....	.....	.....	.....	.....
30	132°	162°	.....	.....	.....	134	.....
35	129	160	.....	.....	.....	.....	.....
40	126	156	140°	113°	125	132	.....
45	123	153	.....	.....	.....	.....	.....
50	120	150	.....	.....	131	.....	.....
55	117	147	.....	.....	.....	.....	.....
60	114	143	.....	115°	123	130	.....
65	112	142	.....	.....	.....	.....	.....
70	109	139	141°*	.....	123°	130	132°
75	107	137	.....	.....	.....	.....	.....
80	105	134	141°*	118°	122°	131	.....
90	99	129	.....	.....	.....	132*	.....
100	95	125	.....	.....	.....	132*	92°
110	91	121	.....	.....	.....	132*	11°
120	87	117	.....	.....	.....	134*	108°
130	83	113	.....	.....	.....	130*	.....
140	80	110	.....	.....	.....	126*	.....
150	77	107	.....	.....	.....	121*	99°

* Temperature of delivery above 212°. Waste-valve closed.

TABLE V.

Pressure above atmosphere.	Maximum ratio water to steam.			
	Calculated from theory	Actual experiment.		
		Hancock inspirator.	Park injector.	Metropolitan injector.
Pounds.				
10	36.5	30.9	.....	.....
15	29.8	.....	.....	.....
20	25.6	22.5	19.9	21.5
25	23.8	.....	.....	.....
30	20.9	19.0	17.2	19.0
35	19.5	.....	.....	.....
40	17.87	15.8	15.0	15.86
45	17.0	15.4	.....	.....
50	16.2	13.3	14.0	13.3
55	15.5	.....	.....	.....
60	14.7	11.2	11.2	12.6
65	14.3	.....	.....	.....
70	13.7	12.3	11.7	12.9
75	13.3	.....	.....	.....
80	12.9	11.4	11.2	.....
85	12 6	.....	.....	.....
90	12.1	.....	.....	.....
100	11.5	.....	.....	.....

DATA AND RESULTS.

Quantities.	Symbol.	Formula.		Quantities.	Symbol.	Formula.	
Discharge head,	h		167.96	Vel. suction lift,	V′	$\frac{Sg}{V}$	1.698
Suction head,	S		3.11	Vel. of discharge, ft. per second,	v′	$\frac{C}{25 \text{ (area dis. pipe)}}$	3.29
Water per hour, supplied,	W		2088.61	Momentum, 1 lb. steam,	m	$\frac{v}{g}$	43.63
Water per hour, delivered,	W + w′		2267.28	Momentum (1 + V′) lbs., delivered,	M	$\frac{V}{g}(1 + V')$	23.228
Wet steam per hour,	w′		178.67	Momentum, suction,	M′	$\pm (1 + V') \frac{S}{V}$	+ 0.6729
Quality of steam,	x		99.6	Efficiency impact,	e	$\frac{M + M'}{m}$	51.78
Dry steam per hour,	w	xw′	177.95	Work delivered, feet lbs. per hour,	F	(h + S) W + w′h	387,298
Pounds of water to one of wet steam,	V′	$\frac{W}{w'}$	11.685	Work heating water, ft. lbs. per hour,	K	778 W (t − t′)	147,528,174
Pounds of water to one of dry steam,	V	$\frac{W}{w}$	11.736	Energy of discharge,	L	$\frac{(W + w') v'^2}{2g}$	384.25
Steam pressure on injector, abs.,	p		83.06	Energy from steam, ft. lbs. per hour,	R	778 [w (H-t) + (T-t) (w′-w)] + F	147,814,180
Steam pressure on orifice, abs.,	p_1	.6p	49.84	Thermal efficiency,	E	$\frac{F + K + L}{R}$	1.0007
Cubic ft. steam per hour,	c	w(vol. one lb.)	904.057	H. P. per 34½ lbs. of steam,	H	$\frac{w}{34\frac{1}{2}}$	5.158
Cubic ft. water per hour, delivered,	C	(W + w′) (vol. one lb.)	36.33	H. P. delivered per hour,	F′	$\frac{F}{60 \times 33000}$	0.1956
				Foot lbs. per 1000 lbs. steam,	D′	$\frac{1000\ F}{w}$	2,176,422
Vel. steam in nozzle, ft. per second (by adiabatic flow),	v		1405.	Foot lbs. per million B. T. U.,	D	$\frac{1{,}000{,}000\ F}{(H - t)\ w}$	2,108,723
Vel. water in nozzle, ft. per second,	V	$\frac{C}{25 \text{ (area)}}$	58.597	Lbs. of steam per H. P.,		$\frac{w}{F'}$	909.7

Table V ; it can be computed from the equation

$$Y = \frac{v}{\sqrt{2gh}} - 1$$

in which Y is the required ratio, v is the velocity of steam, h is the head corresponding to the boiler-pressure above that acting on the injector.

The minimum value of the ratio of water to steam is that required for condensation purposes, and is given in Table II ; it can be worked out from the equation

$$Y = \frac{R - t''}{t'' - t'}$$

in which R equals the heat in one pound of entering steam above zero, t'' equal the temperature of the water discharged, and t' that of the suction-water.

At the limit where the injector would stop these two values would be equal, in which case

$$t' = \frac{t''\, v - R\sqrt{2gh}}{v - \sqrt{2gh}}$$

The limiting valves of the temperature can be obtained approximately by interpolating in Tables II and V.

This method gives Table VI, page 381, which shows the highest admissible temperature of the feed-water as shown by the theory and the highest actually found by trial with several injectors in our own trials and in the trial made by Buel and published in Appleton's "Cyclopædia of Mechanics."

The advantage of having the overflow-valve arranged so that it can be closed is shown in some of the results in the preceding table, by the fact that the injector would draw up feed-water of a higher temperature than would seem admissible by the theory.

With such injectors it is entirely possible to raise the temperature of delivery very much above 212°, with a corresponding increase in the power of the injector to raise water of higher temperature. In such a case condensation takes place under pressure and a less amount of water is required for condensation. The objection to this is the fact that in such a condition the injector is not automatic and is liable to stop for any great change in steam pressure.

The following experiment shows how the temperature of the feed-water and of the delivery-water may be increased by such a proceeding. In one case the temperature of the delivery was 280°, which indicates that condensation took place under a pressure of about 50 pounds absolute.

MAXIMUM TEMPERATURE OF FEED-WATER.

Steam pressure by gage.	Sellers injector.		Hancock injector. Waste-valve closed.	
	Waste-valve closed. Degrees Fahr.	Waste-valve open. Degrees Fahr.	Temp. Feed-water.	Temp. Delivery.
10	110	.....	.....	.....
20	.....	.....	134	175
30	.....	.....	142	174
40	144	.....	142	212
50	.....	.....	143	222
60	.....	.....	143	236
70	152	132	.....	.....
80	.....	.....	143	240
90	.....	.....	142	250
100	133	92	142	246
110	151	112	142	264
120	152	108	142	262
130	.....	.....	142	276
140	.....	.....	143	272
150	144	99	144	280

The record of a test made on the Park injector shows the quantities taken in a test, and the method of application of the theory.

LOG OF TEST.

Test No. 5; made by Burwell and Arnold; date of test, April 28, 1891; injector, Park; manufacturer, Park Manufacturing Company; diameter of suction-pipe, ¾-inch; diameter of discharge-pipe, ¾-inch; diameter of steam orifice, .217; diameter of water orifice, .157; area of steam orifice, .03698; area of water orifice, .01936 inches.

QUANTITIES.	AVERAGE.	CORRECTED.
Time, 3 hr. 7 min. 50 sec.	.....	
Injector gage, lbs. P	70	68.67
Intermediate gage, lbs	.....	
Delivery gage, lbs	70	71.45
Barometer gage, ins., 29.295; boiling point, 210.85 Fahr; atmospheric pressure, 14.39 lbs.	.....	
Suction gage, inches	37.31	
Delivery in feet, h	167.96	
Suction in feet, S	3.11	
Tempt. supply, t'	54.77	54 86
Tempt. delivery, t	145.12	145.65
Tempt. calorimeter	269.12	268.94
Tempt. room	92	
Water supplied	1559.5	
Water delivered	1687.5	
Time of ending, 3 hr. 52 min. 38 sec.		
Duration of run, 44.8 minutes		

AIR-ENGINES.

By Fred. H. McGahie.

THE history of air-engines is a most interesting one, showing how a machine very efficient, considered thermodynamically, may fail to be a commercial machine through inability to overcome practical defects.

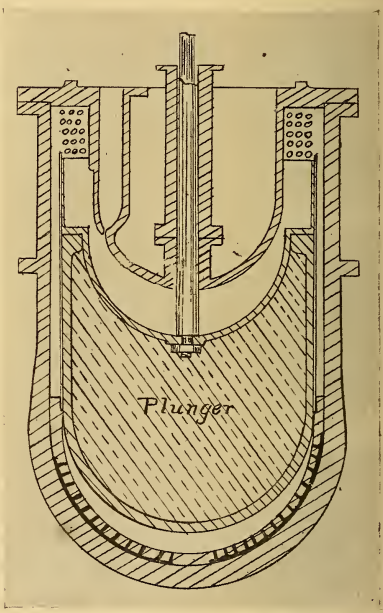
The air-engine is not a success at the present day, inventors having made little progress in correcting those faults that sent it to the scrap-heap some fifty years ago. Its field is practically limited now to small pumping-engines where convenience, safety, and ease of management are the important considerations. These represent the average idea of this class of heat-engines, but there have been air-engines comparing in efficiency most favorably with the best steam plant of modern practice.

As a working fluid, air offers no advantage over steam for transmuting heat into work. But it recommends itself to inventors on account of its safety at high pressures and the corresponding ability to work it at high temperatures through which a larger proportion of the heat can be utilized. Carnot's cycle being followed, the theoretical efficiency is in absolute temperatures

$$\frac{T_1 - T_2}{T_1}$$

where T_1 is the temperature at which the heat is absorbed and T_2 that at which it is rejected. There are two classes of air-engines to be considered, those in which the changes of temperature are made at constant volume and those in which the changes occur at constant pressure.

The Stirling engine, invented by Robert Stirling, 1816, and subsequently improved by him and his brother James, belongs to the constant volume type. The best example of this and air-engines in general was one constructed by James Stirling at the Dundee foundry in Scotland in 1842,—two air-tight vessels, the receivers, connected with the opposite ends of a cylinder in which was fitted an ordinary steam piston. A vertical section of one of the receivers is here shown. A furnace common to both receivers kept their lower ends at a high temperature while water flowing through a number of copper tubes kept down the temperature of the upper ends. A plunger filled with some non-conducting substance as pounded brick and operated by an eccentric, moved up and down in



VERTICAL SECTION OF RECEIVER.

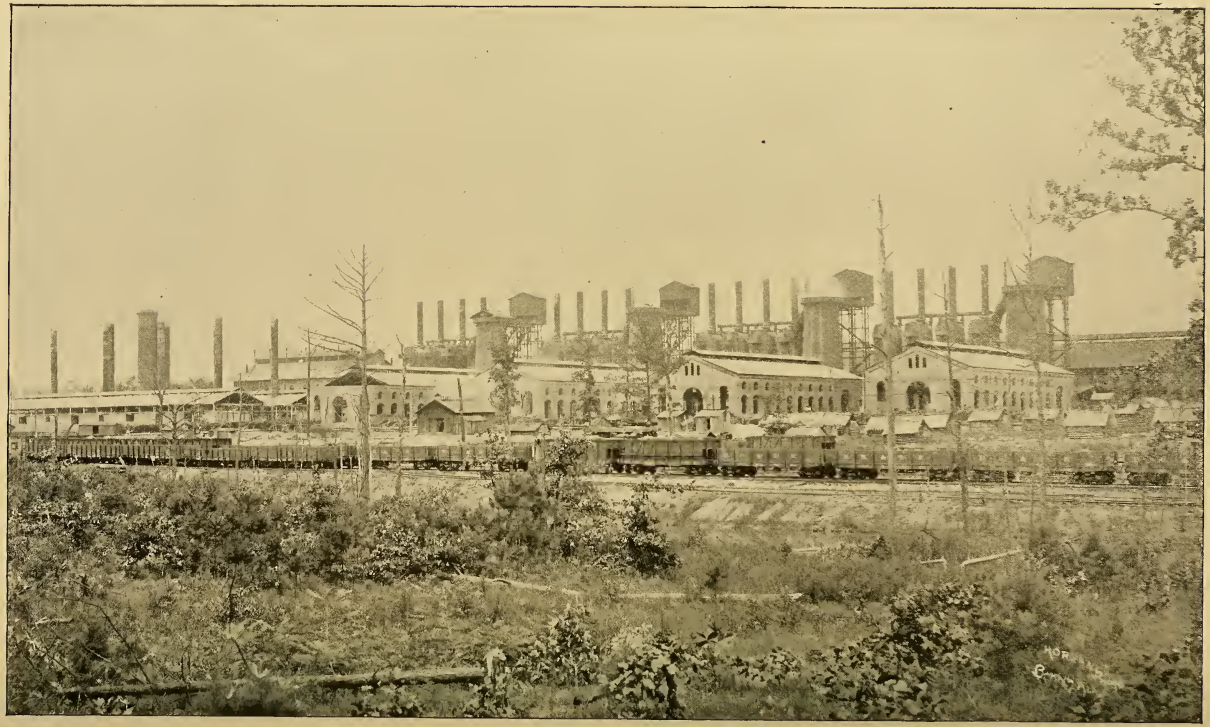
each receiver transferring the air from one end to the other alternately. Between the plunger and the outside shell there was a lining whose hemispherical bottom was pierced with many small holes. The upper part of the annular space between this lining and the outside shell was filled up with thin metal sheets, this arrangement being termed

the regenerator and playing an important part in the economy of the engine. After driving the piston in the working cylinder by expansion, the hot air passes through the regenerator to the cold end of the receiver, giving up most of its heat to the metal sheets so that little heat is left to be abstracted by the refrigerator. When the air passes back, it takes up the heat again and needs little heat to bring it to its highest temperature. In passing through the regenerator the changes occur at constant volume. A great advantage of this apparatus is that it reduces the necessary volume of the working cylinder. To illustrate this, assume in the perfect elementary engine the lowest pressure to be one atmosphere, the absolute temperature of the source 950°, the absolute temperature of the refrigerator 550°, the volume swept through by the piston per single stroke 12 cubic feet. Then the ratio of the greatest volume to the smallest will be without a regenerator 7.5, with a regenerator 1.97, thus reducing the volume about four times. (See Wood's Thermodynamics.) This Dundee engine in order to secure compactness used air compressed to ten atmospheres, the highest pressure being 15½ atmospheres. The working cylinder was 16 inches in diameter with a stroke of four feet and 28 revolutions per-minute. In compactness the engine equaled the best triple-expansion engine of the day. It developed 37 H.P. when tested with a friction brake and gave a H.P. per hour for 2.7 pounds of coal under full load and 2.5 pounds under a light load. The total heat of combustion of the coal was in foot pounds about 9,000,000, giving for the efficiency of the plant 0.133. This is a most satisfactory figure. Where did this engine fail? In order to secure a rapid transference of the heat to the air, a high temperature was necessary to be maintained about the bottom of the receiver which led to their destruction.

Ericsson carried out his ideas on a large scale by building a vessel and fitting it out with a quadruple engine so constructed as to make the change of temperature at constant pressure. Taking Professor Norton's report, 1.87 pounds of anthracite was consumed per I.H.P. per hour, giving the efficiency of the plant as 0.1014, which is the efficiency popularly assumed for a first-class steam plant. The horse power developed was 300, but each cylinder was 14 feet in diameter with a stroke of 6 feet, giving 108 cubic feet to be swept through by the pistons per indicated horse power. This was due to the fact that the air was taken in at atmospheric pressure, making the mean effective pressure 2.12 pounds per square inch. A more fatal factor for the use of the engines in marine propulsion could not have been introduced. The speed developed by the vessel was only seven miles per hour and to have increased it would have soon resulted in engines occupying the whole vessel. Later he developed a land-engine which, though extensively introduced, failed to prove a commercial machine owing to its bulk and the rapid destruction of the furnaces. Afterward he introduced a small pumping-engine that has found many users on account of its convenience.

An engine was exhibited in Paris in 1867 in which the furnace gases were employed. Compressed air was forced into an air-tight furnace ; the gases were admitted to the working cylinder, cut off at part of the stroke, expanded to atmospheric pressure, and then discharged. It proved of no practical use on account of the rapid destruction of the cylinder, piston, and valves by the heat and the grit.

Lately an improved form of Stirling's engine has been brought out in this country that has so far given excellent results. Its merits can be more safely spoken of years from now when it has stood the severe test of time.



ENSLEY FURNACES, TENNESSEE COAL, IRON, AND RAILROAD COMPANY, ENSLEY, ALA.

THE BIRMINGHAM, ALA., IRON INDUSTRY.

By William Kent, M.E.



IN the summer of 1877 the writer made his first visit to Birmingham, saw the blast furnaces at Oxmoor, nearly six miles distant, then the only furnaces in the vicinity, and the iron mines on Red Mountain, close at hand, and published in the *American Manufacturer* his impression that Birmingham was destined to be the center of a great iron industry. At that time Birmingham was a promising young city with about 3000 inhabitants, and had already achieved the title of the Magic City. It was a city made to order, its beginning being the incorporation in December, 1870, of a company called the Elyton Land Company, whose avowed purpose was to build a city. One of the incorporators purchased 4150 acres of land, at $25 per acre, paying three-fourths cash and one-fourth in stock of the company. Its first office was a two-roomed house which had been used as a section-house by the Alabama and Chattanooga Railroad. Its first contract was one for the operation of a brickyard to make bricks for the building of the city. It laid off streets and avenues, and on June 1, 1871, it opened an office for the sale of lots, the first lot, now said to be worth $50,000, being sold for $100. The building of the new city progressed at a tremendous rate, so that in 1873 it had a population of 4000. Then the panic of 1873–78 struck the town, the cholera came in the same year, and the inhabitants who had been so busy for two years building a city found there was nothing for the city to do after it was built, and they began seriously to inquire what reason it had for its existence. The population dwindled down to less than 2000 in the next five years, and the Elyton Land Company had difficulty in paying interest on its indebtedness. In the words of Dr. Caldwell, the president of the land company, "gloom had settled like a dark pall over the young city, while despair had settled upon its people, who were formerly buoyant with hope." Such was the city at the time of the writer's visit in 1877. It had a beautiful location, a fine climate, two railroads, one to Nashville and the North, and one to Chattanooga and the Northeast, and prospects of one to Atlanta, but it had no industry. But its great hope was that it was destined to make pig-iron, and dispute with Pittsburgh for the supremacy in the iron industry. Pig-iron is a poor reliance for a great city. Pittsburgh and Chicago were great before they had any pig-iron industry worth speaking of. The greatest plant for production of pig-iron in the United States is in or near the town of Braddock, Pa., and who knows anything of Braddock, except that Washington fought his first battle there and that it is near the Edgar Thomson steel-works? Other pig-iron cities are Johnstown, famous for its flood; Steelton, Pa., and Sparrows Point, Md., but they are not great cities at all. Yet Birmingham has become a great city, and to pig-iron it owes, if not its greatness, at least its second start in the direction of greatness. In August, 1879, quoting again from Dr. Caldwell, "the first rays of the rising sun of prosperity began to illumine the long-darkened horizon of Birmingham and the Elyton Land Company when it was announced that the company had donated to Hillman & DeBardeleben twenty acres of land at the west end of the town upon which to erect a blast furnace. In the spring of 1880 work upon Alice furnace No. 1 was actually commenced. From



THE SLOSS IRON AND STEEL COMPANY'S CITY FURNACES, BIRMINGHAM, ALA.

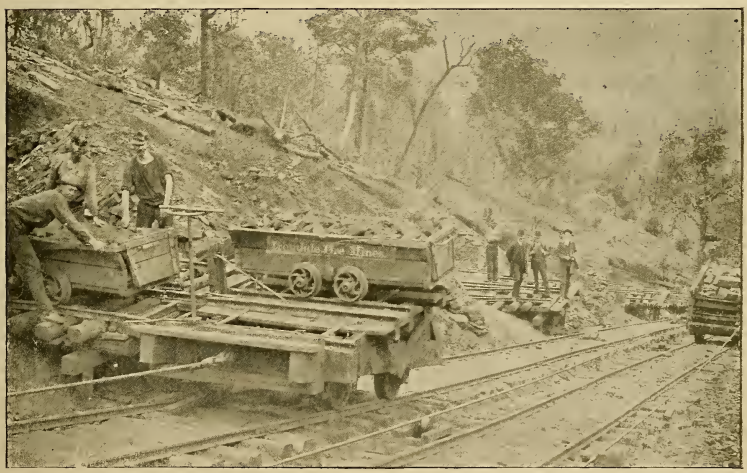
this time the population of Birmingham began slowly and steadily to increase. During the year 1880 the building of the Birmingham rolling-mills was also commenced." The total sales of property and the average price per lot inside the corporate limits of Birmingham from 1880 to 1883 were as follows :

	Sales.	Per lot.
1880	$69,448	$260.00
1881	106,995	360.00
1882	176,713	511.71
1883	355,817	905.49

In 1883 the Land Company paid off its indebtedness, and declared its first dividend since its organization in 1870, prices obtained for city lots were equal to those asked in the North for similarly situated blocks in cities of 200,000 inhabitants. A reaction in these imaginary land values has since taken place, and the purchasers of 1887 are longing for the day when the prices of that year shall again be realized.

A local publication gives some statistics of the city and its surroundings as follows :

	Population.
1880	3,086
1885	21,347
1888	45,000
1890	49,686
1891	54,819

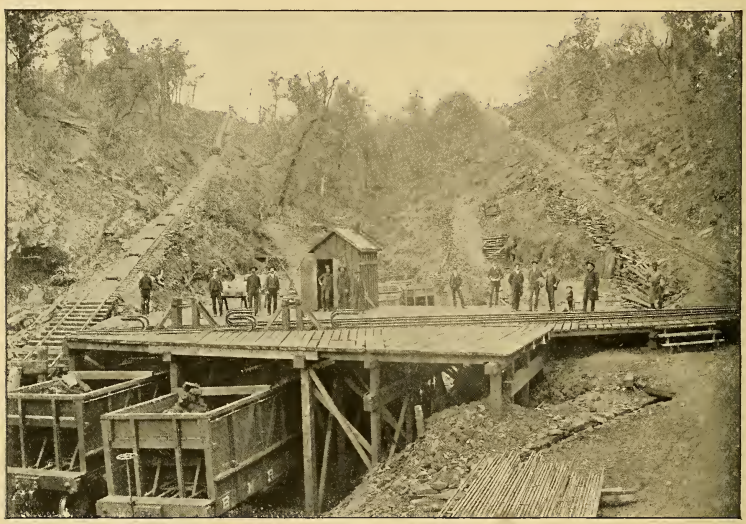


THE IRONDALE ORE MINES. TRANSFERRING THE ORE CARS TO PLATFORM CAR ON THE GRAVITY RAILROAD.

the amount being $200,000, or 100 per cent. of its capital stock. Then began a season of prosperity, the like of which is probably unparalleled in the history of land "booms," culminating in 1887, when the Elyton Land Company declared dividends in cash, stocks, and bonds amounting to $4,610,000, or 2305 per cent. of its par value. Its stock, of the par value of $100, which in 1875 was unsalable at $15, rose in 1887 to $4000 per share, at which price several shares were actually sold. The

Suburbs, reached by horse-car or dummy line, Pratt Mines, Ensley City, Gate City, Oxmoor, Clifton, Coalburg, Bessemer, Powderly, and a number of others, aggregating at least 20,000. Altitude above the sea, 602 to 900 feet. Death rate per 1000 in 1890: white, 13.07 ; colored, 24.94. Railroads, Louisville and Nashville, Queen and Crescent, from Cincinnati to New Orleans ; Savannah and Western, to Columbus, Ga. ; Kansas City, Memphis and Birmingham, to Kansas City ; Georgia Pa-

cific, Atlanta, Ga., to Greenville, Miss.; Mobile and Birmingham, to Mobile; local roads of the Tennessee Coal, Iron, and Railroad Company, the Mary Lee Coal and Railroad Company, and the Birmingham Mineral Railroad, to various points in the vicinity. Freight traffic, over 6,000,000 tons. Passenger ticket sales, $656,347. Assessed valuation, 1890, $16,000,000. Bank capital and surplus, $4,000,000. Clearing-house transactions, $35,814,071. Street and suburban railroads, horse, electric,



IRONDALE ORE MINES. GRAVITY RAILROAD AND TRANSFER TRACK.

and dummy, 88¾ miles. Daily output of coal mines in Jefferson county, 17,600 tons; of coke ovens, 5231 tons; of iron ore, 7000 tons. The writer does not place entire confidence in the figures of this local publication, for the reason that it is greatly in error in its statement of pig-iron production of the State, giving it as the second largest producer in the Union, with a product of 1,780,900 tons in the year ending June 30, 1890, and claiming that it will produce over 2,000,000 tons in 1891, while the official figures show that it is surpassed by Ohio as well as by Pennsylvania, and produced only 914,940 net tons in 1890, and 891,154 tons in 1891. A million tons more or less, however, is a small error for a land boomer, one of whom asserts, even with vehemence, that the Ensley blast furnace plant is the largest in the world, and that it has 13 stacks. The true figures of the pig-iron industry, however, are sufficiently eloquent. They show that Alabama increased its production from 227,438 net tons, or 5.02 per cent. of the total production of the United States in 1885, to 914,940 tons, or 8.88 per cent. in 1890, and 891,154 tons, or 9.61 per cent. in 1891. Notwithstanding the depression of the trade in 1891, which caused the production in the whole United States to decrease from 10,307,028 tons in 1890 to 9,273,455 tons in 1891, or over 10 per cent., the production in Alabama decreased only 23,786 tons, or only 2.58 per cent.

Probably three-fourths of all the pig-iron production of the State of Alabama is now made in Birmingham and its immediate vicinity within a radius of 15

miles, a district which in 1877 contained only two small furnaces at Oxmoor. The following is a list of the furnaces, their estimated capacity being that given by a Northern engineer, resident in the district, who is well acquainted with them all:

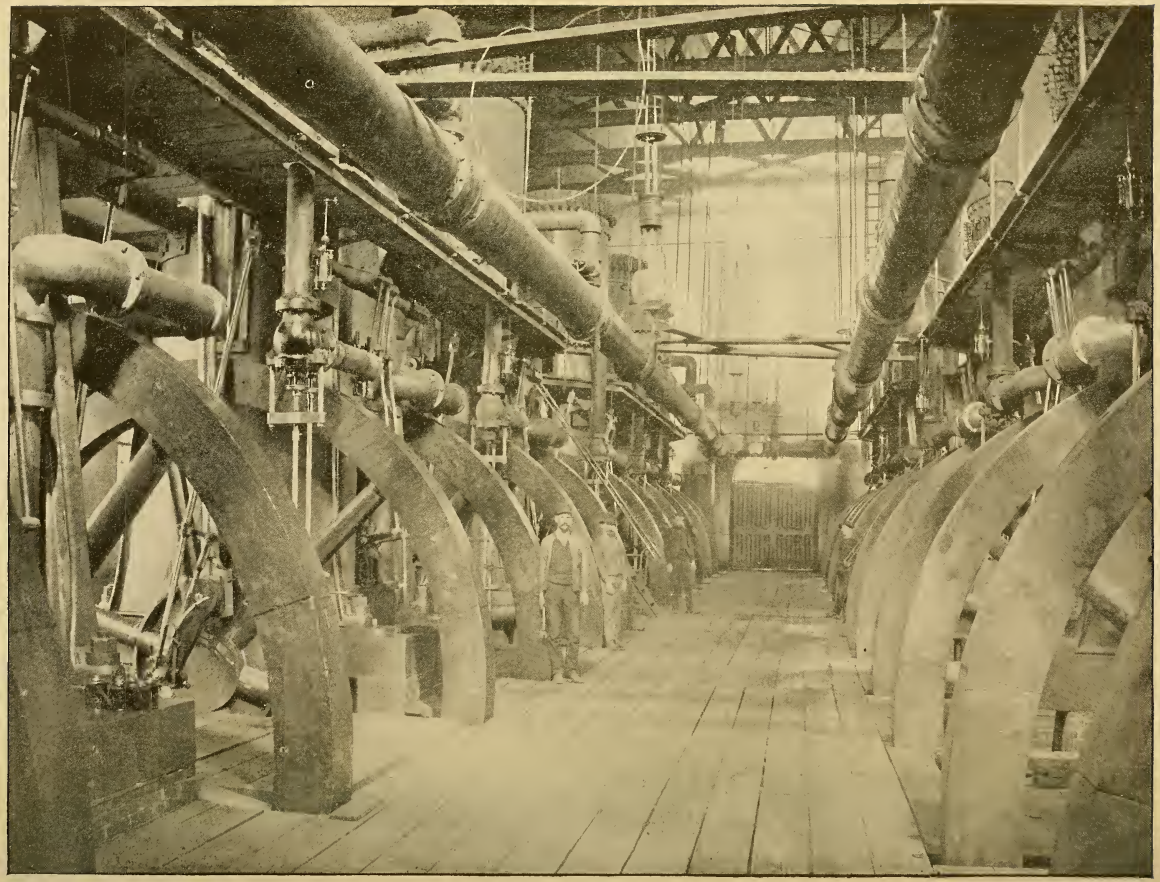
Of these twenty-five furnaces, all are in blast with the exception of one of the Ensley furnaces, which is being repaired and will soon be put in blast, and the Mary Pratt furnace, which is out on account of a pending reorganization of the company,

The fact that 23 out of these 25 furnaces are now running notwithstanding the present overproduction of pig-iron in the country at large, and the lowest prices that have ever been known, is strong evidence of the stability of the advantages in fact exist to a greater or less extent, but they are all offset by the supreme advantages of short distance of transportation of raw material and inexhaustible supplies of both ore and coal, within five miles of each other, cheaply mined and above water-level. The Woodward furnaces have their own railroad for both coal and ore supply, the Tennessee Company its own road for coal and coke, and the other furnaces have to pay only about 25 cents per ton freight for their supplies. Most of the furnaces own both ore- and coal-mines, but some of them buy all their raw material. When this position is contrasted with that of Pittsburgh, which has to pay for 1000 miles' freight on ore, and with that of Chicago, which has to pay for 500 miles' transportation of coke,

Name of Company.	Name of furnace.	No. of furnaces.	Location.	Daily capacity.
DeBardeleben Coal and Iron Co.		5	Bessemer.	500
" " " " " "		2	Oxmoor.	200
Tennessee Coal, Iron, and Railroad Co.	Alice.	2	Birmingham.	170
" " " " " "	Ensley.	4	Ensley.	540
Sloss Iron and Steel Co.	City.	2	Birmingham.	200
" " " " "	North Birmingham.	2	North Birmingham.	240
Pioneer Mining and Manufacturing Co.	Thomas.	2	Thomas.	250
Woodward Iron Co.		2	Woodward.	200
Williamson Iron Co.		1	Birmingham.	65
Mary Pratt Furnace Co.		1	Near Birmingham.	65
Vanderbilt Iron and Steel Co.		1	" "	65
Trussville Furnace Co.		1	Trussville.	100
		25		2595

Birmingham iron industry. The furnaces are shipping iron to every part of the United States, and even into Canada. Some of them are piling up iron, and refusing to make contracts for delivery in the second half of the year at present prices, in the hope that prices will then be higher, but stocks are not yet large enough nor prices low enough to force any of them to go out of blast.

This remarkable position of the Birmingham furnaces has been reached in spite of great disadvantages. Critics of the Southern furnaces have pointed out that they are handicapped by great distance from market, most of their iron being sold north of the Ohio river; by lean ores, poor coke, inefficient labor, heavy bonded indebtedness, imperfect equipment, poor management, and low grade of product. Many of these dis- it is easily seen why Alabama iron is sold in both Pittsburgh and Chicago. The writer, however, has no sympathy with those who would boom the South at the expense of other sections of the country, and thinks that Edward Atkinson, the eminent statistician, made a great mistake in his widely-published prediction that the Southern part of the great Appalachian range is to be "the future great center of the iron production of the world." There will be no one great center, but several at widely-separated locations. Both Pittsburgh and Chicago are increasing their iron-producing capacity at a more rapid rate than Alabama. Notwithstanding the great increase in Alabama from 1885 to 1889, its increase was less than that of Allegheny county, Pa., and but little over one-third of that of the State of Pennsyl-



ENGINE-ROOM OF THE ENSLEY FURNACES AT ENSLEY, ALA. 12 WIEMER BLOWING ENGINES, CAPACITY 18,000 CUBIC FEET EACH PER MINUTE.

vania in the same time. Pittsburgh and Chicago make iron suitable for Bessemer steel. Alabama makes none. They convert their iron into finished shapes, ready for the final consumer. It has to ship its raw iron hundreds of miles to find a market as raw iron. Nevertheless, the Alabama iron industry is destined still to increase, and it has an assurance of permanency equal to that possessed by any other section. The

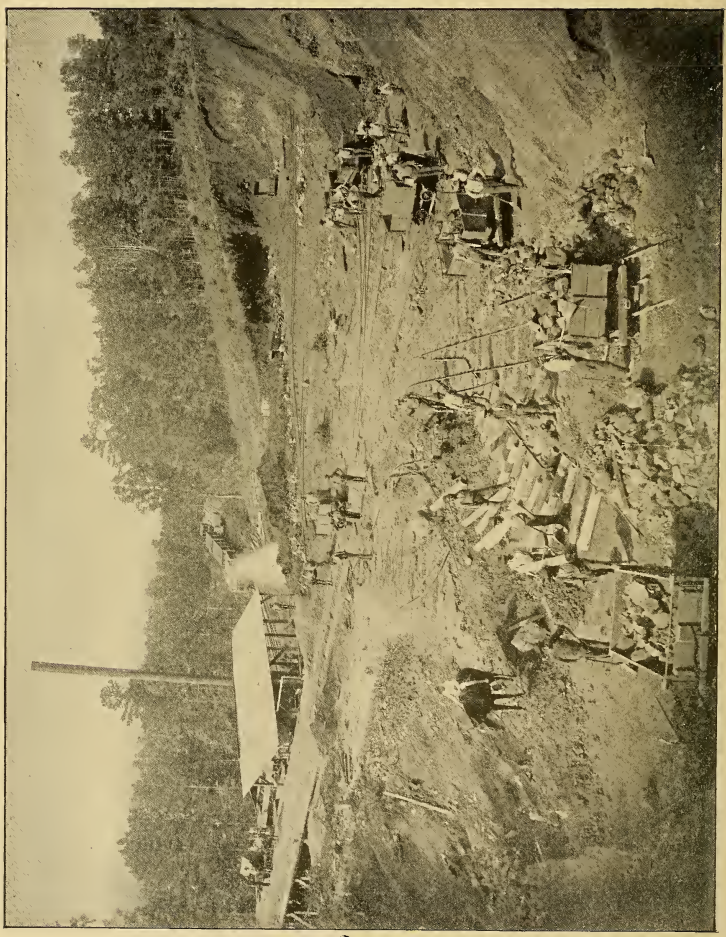
The cost of making iron in the Birmingham district, as in all others, varies according to the conveniences of the furnace plant, the character of the ore veins, and the management. The coal is mined by contract, the prices paid for cutting ranging from 45 cents in a 4-foot seam to 60 cents in a 3-foot seam. Dead work, haulage, repairs, royalty, etc., will bring the total cost to nearly $1 per ton. As one ton of coal makes 0.6 ton



THE THOMAS FURNACES, FOUR MILES FROM BIRMINGHAM, ALA.

plants are being steadily improved, reducing the labor cost per ton. The cost of mining is being reduced by the introduction of improved methods. The coke is much better than it was some years ago, and is likely to be made equal to that of Pennsylvania by the adoption of a washing process, to reduce the amount of ash and sulphur in the coal. The demand for consumption in the South is increasing, and is likely to increase more rapidly in the future.

of coke, the coal per ton of coke costs $1.67, and the labor of making coke, repairs, freight, etc., brings the cost of coke to nearly $2.50 per ton. The red fossilliferous ore costs from 65 to 80 cents per ton at the mines, varying according to the hardness and to the method of mining. It contains about 45 per cent. of iron as an average. Brown hematites, used by some furnaces as a mixture, are cheaply mined, but they require to be washed to bring their



THE CHAMPION BROWN ORE MINES. ORE WASHER AT THE LEFT.

content of iron up to 50 per cent. Adding freight and a small margin for profit will make the ore mixture cost about $1 per ton at the furnace. Limestone is very cheap, and including freight costs about 70 cents per ton. Labor varies at the different furnaces according to the capacity of the furnace. As an average it may be taken at $1.75 per ton of iron made. Repairs and incidentals are frequently put as low as 50 cents per ton, but to be on the safe side not less than $1 per ton ought to be taken. On this basis the cost of pig-iron will be figured as follows :

Ore, 2¼ tons, @ $1 00	$2.25
Coke, 1½ tons, @ $2.50	3.75
Limestone, ½ ton, @ 70 cents	.35
Labor and incidentals	2.75
Total	$9.10

Gray forge iron has been sold as low as $9.25 per ton at the furnace, and No. 1 foundry below $12.00, so the margin of profit depends entirely on the condition of the furnace and the skill of management, which will cause it to produce as large a percentage of foundry grades as possible. Considering the enormous amount of capital needed to construct a good blast-furnace plant, to pay for coal- and ore-lands, to open the mines, and the reserve required for working-capital, it is evident that the margin of profit is not enough to encourage the investment of new capital in the business, although it is enough, with good management, to keep the furnaces now running from going out of blast. The margin of profit is probably fully as great as it is in the business in any other location.



THE GREAT ORE SEAM ON RED MOUNTAIN, NEAR OXMOOR, ALA. 22 FEET THICK.

The iron industry of Birmingham and vicinity is not entirely confined to the manufacture of pig-iron. There are three large rolling-mills,—that of the Birmingham Rolling-Mill Company, with

a capacity of about 100 tons per day ; the Gate City rolling-mill, and the Bessemer rolling-mill, each with a capacity of 80 or 90 tons. The first of these mills was built in 1880, and has had a very successful career. It produces bar-iron of all shapes and sizes, light angles and rails, and plate- and sheet-iron The Gate City mill makes merchant bar. The Bessemer mill is equipped for plate, sheet, and bar, and is an excellent mill, but is now idle, the company having been forced into bankruptcy by the failure of the United States Rolling Stock Company, whose paper it had endorsed, and not on account of the lack of profits in the manufacture of iron. There is also a small steel-works close by the North Birmingham furnaces, containing one basic open-hearth furnace, built by the Henderson Steel Company, and run, it is claimed, successfully for a short time, but it also was carried down by the failure of the Bessemer Rolling-Mill Company. It is probable that the rolling-mill will soon be started again, but there is no immediate prospect of the starting of the steel-works.

The problem now agitating the district is the establishment of a steel-works, and it is probable that one will be built before long by one of the large blast-furnace companies. The undertaking of a steel works in this section is one of considerable difficulty, and whoever starts it will need to be possessed of large means, and great courage and patience. The ores are not suitable for the acid Bessemer or open-hearth processes, being too high in phosphorus. They are too low in phosphorus for the basic Bessemer, and the irons now made are too high in silicon for the basic open-hearth. The process which offers the best chance of success in this district is a combination of the acid Bessemer with the basic



THE BIRMINGHAM ROLLING MILLS.

open-hearth, the former for desiliconizing the iron, and the latter for dephosphorizing. This duplex process, however, involves a more expensive plant, double handling, and greater waste than a single process. After the steel is made, the next question will be to find a market for it.



COKE OVENS OF THE CAHABA COAL AND COKE COMPANY.

It will not likely be profitable to ship the ingots North to be rolled, nor is there at present any great Southern demand for them. In the writer's opinion the steel-works, to be assured of success, should possess a rolling-mill which would put the steel into finished shapes, such as plate and sheet of all thicknesses, and in addition to this a department in which a large portion of the plate could be utilized in the manufacture of tanks, boilers, and plate structures in general, which would be likely to find a large home market. The district already has other works besides the rolling-mills which consume a portion of its pig-iron product, such as a large stove-works, a pipe-works, and several machine-shops and foundries. There is room for more of such works, and many Northern concerns who are now large consumers of Southern pig-iron would probably find it to their advantage to establish branch works in Birmingham or vicinity.

MERCURIAL COLUMNS.

By A. B. Calkins, M.E.

AN apparatus much used by the professional engineers for purposes of comparison and the verification of instruments under the head of pressure-recorders and gages is the mercurial column. Its use, as very well known and understood, is applicable for showing pressures below and above the atmosphere. Its importance in establishing the principal factors used in calculations connected with the elastic properties of fluids, gases, etc., is also very well understood.

However, features in the construction of the apparatus used, up to the present period, have tended to make the manipulation of the same and eventual gathering of comparative data a matter of some conjecture as well as labor and expense.

The use of the mercurial column of necessity having been brought into the labors of the writer, in establishing correct and equal effects in the operations of the steam-gage, with the operations of the indicator-spring, has been the means of developing new and important features in this most important of comparative apparatus.

Mercury is undoubtedly the most fitting substance for use in the apparatus necessary for standardizing pressures on the square inch or square centimeter, its properties being such that at the ordinary temperatures of the atmosphere evaporation is imperceptible, its density great, and its fluidity unchanged, or affected by oxidation. Its dilation or expansion is nil, so long as the temperatures remain constant, during a comparative test.

From these fixed characteristics, therefore, the standard of comparison for all pressures on the square inch or kilogrammes on the square centimeter is a column of mercury, the height of the column varying as the pressure compared.

A column of mercury 760 millimeters high, at 32° Fahr., or 0 centigrade, balances the pressure of the atmosphere. Its English equivalent is 29.9218 inches. These pressures vary continually, the barometer showing from 28.5 inches to 30.5 inches in its heights.

The pressure on the square inch in pounds, as represented by the height of mercury for the mean atmospheric pressure, is the weight of a cubic inch of mercury (.491157 pounds), at 32°, times 29.9218, or 14.6963 pounds, and the equivalent of 1 pound on the square inch in height of mercury is rated by the quotient of 29.9218 divided by 14.6963, which is 2.03601 inches.

The unit of elasticity, therefore, in mercurial heights for pounds on the square inch is 2.03601 inches. The custom has prevailed up to a recent period of constructing the apparatus for showing heights of mercury with a perpendicular tube leading from a larger vessel at its base filled with mercury (Fig. 1). The operation of this apparatus is simply to pump water into the vessel at the base, forcing the mercury out of the larger into the smaller tube, the heights of mercury sustained by the force-pump being recorded by means of a float riding upon the mercury in the tube.

Attached to the float is a fine string, which is carried up and over a pulley fastened on the top end of the tube. This string is dropped down alongside the pipe. Fitted on this string is a sliding pointer, which is used to mark the distance passed through by the float inside the pipe, and in consequence the distance passed through by the mercury.

It is evident from this construction that a scale or other medium showing linear distance must be brought into conjunction with the pointer, in order that a connected reading from start to finish may be accomplished.

A scale, therefore, graduated into 20 equal divisions, and, again, each into four subdivisions, is placed vertically before the operator.

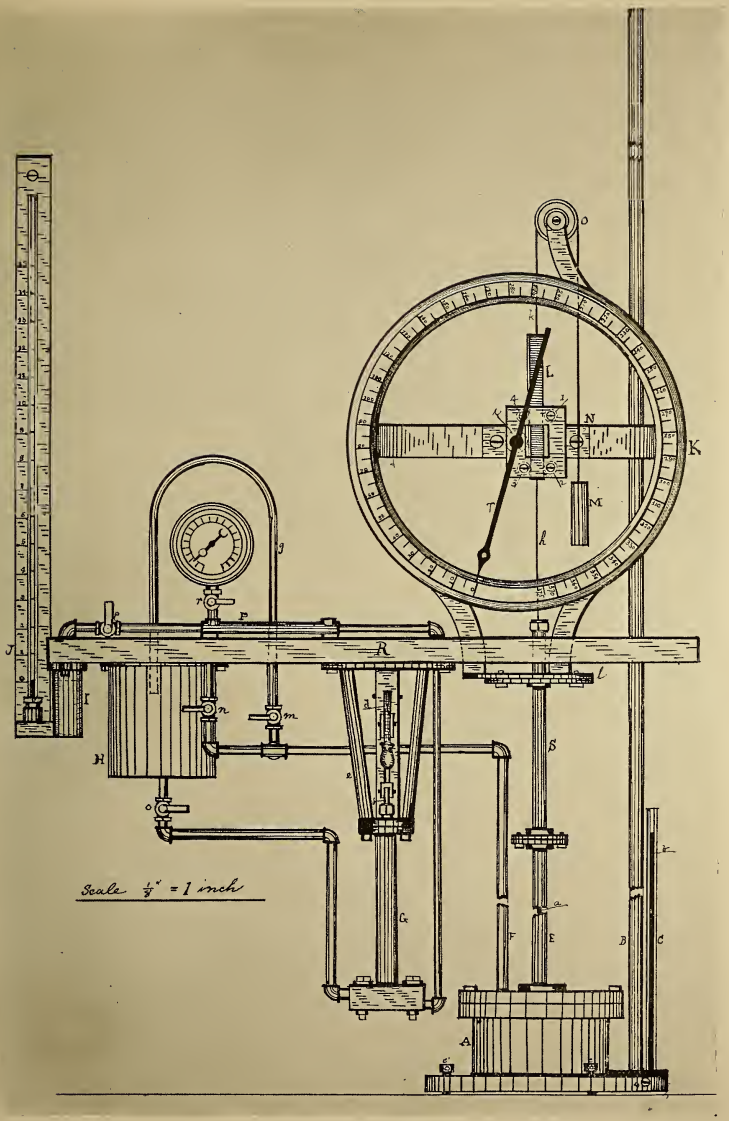


FIG. 2. MERCURIAL COLUMN.

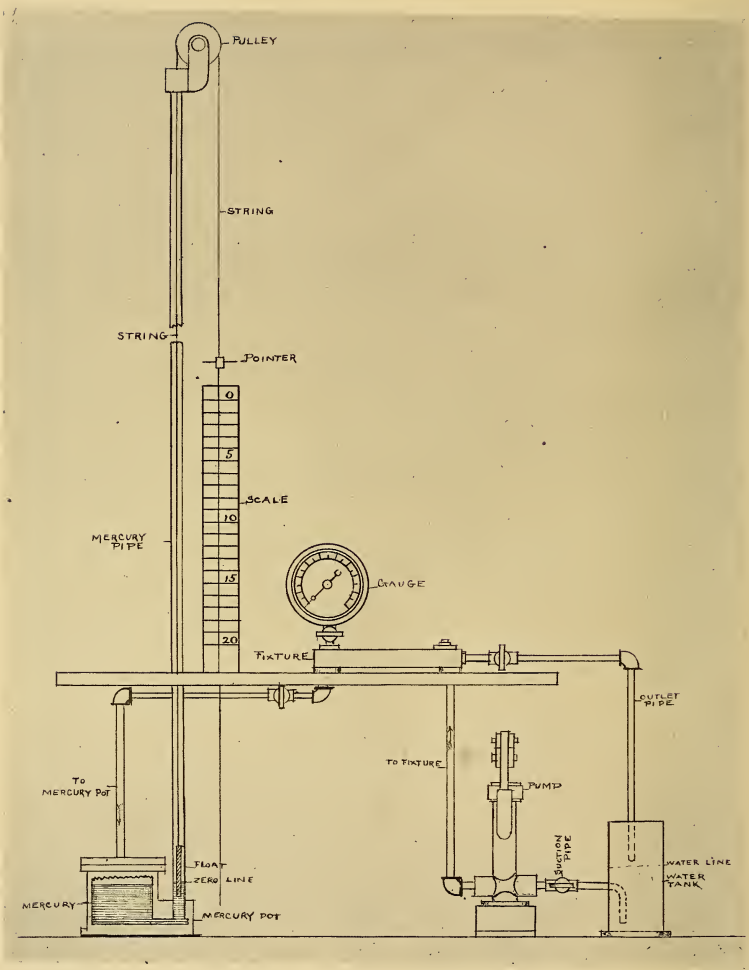


FIG. 1. MERCURIAL COLUMN APPARATUS.

The 20 main divisions represent 20 pounds on the square inch, or in linear distance 20×2.03601, or 40.72 inches. The subdivisions are equivalent to one-half and one-fourth pounds, and are respectively ½ and ¼ of 2.03601 inches. From the first impulse of the pump by the operator the float goes up and the pointer downward, having started at zero on the scale at its top end. When the 20 marks, or 20 pounds, have been covered, the pointer is slipped upward on the string and a fresh start taken. These operations are repeated until the whole range of the column has been run through, the amount never exceeding 300 pounds on the square inch. Upon consideration, it will appear that several changes for error creep in by this manner of manipulation.

First, correction for the fall of mercury in the pot during the elevation in the tube is necessary, this correction applying to the scale, it being as much shorter for each pound as the total fall in the pot divided by the number of pounds on the square inch attained; as, were 300 pounds attained, and the fall 2 inches in the pot, the correction for each pound would then be 2 inches $\div$ 300 = .0066 pounds, and for 20 pounds or the full scale, .0066 $\times$ 20 = .1320 inches. By this correction the zero point is taken care of at all elevations.

In some constructions the zero point is maintained by forcing a piston into the mercury in the pot, causing it to rise about the same, proportional to the displacement. At every reading, however, the piston must be forced down, and taken in conjunction with other devices attached, such as hand-wheels, packing boxes, and finely constructed sights, to tell the point of coincidence, its advantages can be very much questioned.

Second, chances for error are in the extreme vibrations of the mercury in the pipe during the operations of the pump, causing the float to rise and fall violently, making an exact reading impossible. The stretch of the string, which is necessarily long (nearly 1225 inches), caused by heat or moisture, changes the last reading from the first, at times, as much as 2 inches. The slipping of pointer on the string also tends to alter the last from the first reading. Friction from float in the pipe creates errors, and, all in all, the chances of duplicate testing by mercurial column is an impossibility. In addition to the mechanical errors of the system, it is necessary that three men shall be employed during a comparative test with the column,—one to handle the pump, one to slide the pointer on the string, and one to announce the pressure.

With these obstacles in view it is found commercially impracticable to bring the mercurial column into general application for testing purposes as it is constructed.

A few experiments, however, have demonstrated the fact that a construction is possible wherein all the defects of the old system disappear, and possibilities of covering a greater field of operation made apparent.

By this it is meant that pressures up to 1000 pounds on the square inch, and even more, can be correctly recorded by heights of mercury, and which would be impossible by the old system on account of the great length of the string attached to the float and the slipping of the pointer on the string.

Even were the column of glass, to maintain the enormous pressure, it must be of great thickness at its base, and an elevator or stairway built about it, so that an operator can mount and take readings. These readings would have to be made coincident with the manipulations of the pump, or too much or too little is the result.

By the new method it is easy for one man to sit at the testing table and manipulate one valve only, to show pressure from 0 to 1000 pounds or more on the square inch.

The features of the new system are similar to the one in question in so far as the perpendicular pipe and larger vessel at its base and force-pump are concerned, the recording mechanism, however, being entirely another departure. In fact, it is believed to be the first application of this method put into practical operation. In arranging the system to give the results desired, that is, uniformity of action, and coincident position of the recording-hand, with the

mercury in the pipe at its different heights, all friction and leakage must be eliminated. The joints where pipes are screwed together, cocks, flanges, unions, etc., are all easily made up; the connecting wire *h* leading from the float-rod *a* to rack *L*, however, must pass through a packing-box *S*, so arranged that no friction or leakage exists appreciably.

This result is accomplished by means of a long tube with internal chamber so arranged that the wire passes through substances that do not solidify or compress under pressure and which have a repellent action for water.

In experiments with pressures as high as 375 pounds per square inch, neither friction nor leakage is apparent, and the sensitiveness is as great as at 1 pound. The recording-hand responds to the pulsations of the pump with regularity and precision and without the violent movement so common in the recording-pointer in the older system, thus giving the operator the opportunity of making note of all pressures attained with extreme accuracy and without more than one trial.

Fig. 2 is an outline drawing of the new system. The pot *A*, holding the mercury, is fitted with leveling screws and is bored inside to a diameter equal at top and bottom. The tube *B* is of steel, and bored smooth and of equal diameter from end to end. This tube previous to erection is graduated into spaces 60 inches apart. They are provided to prove the height of the mercury at any desired point against the position of the pointer and thus verify its readings. This, however, is preliminary work, and has only to be gone over once, and that at the time of erection, as the action is invariable once set right. *C* is a small glass tube, standing in the channel from the pot, from which the large column tube is projected. This is for ascertaining the position of zero after all the columns of water in pipes are on.

We make note of the position of this auxiliary height, as compared with its distance from some one of the marks previously made on the pipe. Having established this distance, the mercury in this tube is cut off from the main body by means of a cock situated between them.

The use of the marks put upon the pipe will be made apparent, having established the zero point, for without them measurements would be difficult, and besides, one set series of distances is preferable to continued and repeated measurements, especially where accuracy is desired. So, then, for example we find the zero point 25 inches below one of the marks put upon the pipe. We desire to show with the column pressures up to 375 pounds per square inch. The distance lineally expressed in inches for this pressure is 763.5 inches. By dividing 763.5 by 60 we readily find the number of spaces required. If the remainder is more than 25 inches, the difference of the remainder and 25 must be added to the top space. If the remainder is less than 25, then the difference must be subtracted from the top space.

763.5 ÷ 60 = 12 spaces and 43.5 inches over 43.5 — 25 = 18.5 inches, which must be added to the top space. This position denotes the distance the mercury is elevated to for 375 pounds on the square inch, the chances for error in measurement being reduced to a minimum by the use of the lines previously made. Riding upon the top of the mercury in pot *A* is a peculiarly shaped float, made to resist oxidation, and very light, with a diameter nearly the full diameter of the pot. Attached to the float is a stiff rod *a*, leading upward, to allow of connecting the fine wire *h*. Situated in triangular form at top center, and bottom sections of the rod, are rollers, the diameters of which keep the rod from rubbing against the side of the tube *E*. The fine wire attached to top of rod *a* connects directly to rack *L*, which engages pinion *i*, through which a circular motion is transmitted to the hand *T*. The counterbalance *M* is so weighted that the predominance of weight shall be apparent in the float and connections. The difference will be enough to allow the float to settle into the mercury just enough to destroy the convexity of the top surface of the same.

Presuming now that the mechanism is ready to put into operation to show pressures above the atmosphere, shut cocks *p* and *m*, and open cocks *o* and *n*. By applying force-pump *G*, water is

drawn out of tank *H* through cock *o*, and forced into the mercury pot *A* through cock *n*, chamber *P*, and pipe *F*.

The mercury will be forced up the column by the water displacement, and in consequence fall in the pot *A*. During this fall the float follows on the top of the mercury, carrying with it the mechanism attached to the float-rod *a*.

The maximum pressure attained in the column from which the data herewith is accumulated is 375 pounds on the square inch, as previously stated, above the atmosphere. The fall of mercury in the pot being exactly 4.25 inches, and the multiplication of motion at the end of the recording-hand being 16 to 1, the distance traversed on the circle would be $4.25 \times 16 = 68$ inches. This 68 inches provides a distance of sufficient length which, divided into 375 parts, gives for each part or pound .1813 inches of distance, an amount readily seen and compared to. The method, however, of ascertaining the exact distance passed through by the hand from *o* was as follows: The calculated distance being 375×2.03601, or 763.5 inches, was measured off on the pipe above *o* with the aid of the marks above referred to. The fall in the pot being 4.25 inches, it is necessary to make correction of that amount by subtracting it from 763.5 inches, leaving 759.25 inches.

This being the corrected distance the mercury should pass through to show 375 pounds on the square inch, a hole $\frac{1}{100}$ of an inch in diameter is here made. Pressure is now applied by the force-pump until the mercury shows at the hole made in the pipe. The position of the hand is noted and a mark made on the dial. Pressure is now let off entirely and the operation repeated several times to prove the accuracy of the mark made. Coinciding at every trial it is accepted as the desired point. A simple calculation in connection with a Brown & Sharpe indexing machine made the subdivisions, or 375 parts, easy to produce.

To verify the accuracy of these subdivisions, holes $\frac{1}{100}$ of an inch in diameter are made in the tube at every 25 pounds' position. The hand on its respective mark coincident with the elevation of the mercury to its respective height was conclusive proof of the accuracy and reliability of correct performance and workmanship.

These remarks go to show operations carried on with a hand force-pump, operated in similar manner to the old system.

Other and advantageous features in the operation of this system are the electrical attachments, reducing the manipulation during comparative tests to operating an electrically-worked valve, all the other mechanism working in an automatic manner under the influence of pressure. In place of the hand-pump a reservoir or drum for accumulating a pressure a few pounds in excess of the full value of the mercury column is provided. The pressure is maintained by a pump actuated by steam or belts; a relief-valve is affixed so that a constant pressure is maintained. This drum is piped to the mercury pot the same as for the ordinary pump. Intervening between the pressure drum and pot is a valve worked by electrical current and operated to open and shut by pushing a button. Upon the dial of the apparatus on every 5-pound mark are made projections of $\frac{1}{16}$ inch and $\frac{1}{100}$ inch wide. The recording-hand is fitted with a piece of platinum wire on its extreme outer end.

Connections are made to a battery in the usual manner so that when the hand under the influence of pressure begins to revolve it comes in contact with the projections and provides the means for making record of the particular pressure instantly. For example, a steam gage is to have its dial marked coincident with the heights of mercury. It is attached to the fixture *P*; the hand is taken off and substituted with one fitted with an electrical marking apparatus on its outer end. This hand is wired so that when the contacts are made with the hand on the mercury dial and projections a needle or type, as the case might be, is projected against the dial to be marked. As the pressure increases, so the hands go around the circle, the longer hand making and breaking contact on the dial at every 5 pounds, while the marking hand on the gage being tested or marked makes simultaneous

and coinciding marks on its respective dial. Gages to be tested comparatively only, are simply attached to the fixture, while the hands of each are noted as to their coincidence.

The pressure is wire-drawn into the mercury pot from the pressure reservoir through the medium of the electrical valve, and let off in the same manner through another.

The foregoing remarks are from data accumulated from operating a column constructed for the purposes of demonstrating the principles involved, and it is with extreme gratification we are able to state that the experiments have terminated by showing the most positive and duplicate results from repeated trials against different methods of proof establishing for a certainty the fact that reliable work can be carried on with the mercurial column without undue expense or conjecture. Additional to the apparatus for showing pressures above the atmosphere an auxiliary column *J* with air-pump is attached for showing pressures below the atmosphere. The column consists of a glass tube with the necessary corrections in the scale for the fall of mercury in the pot. A rubber tube connects the air-pump with column at its top. This glass tube is also used to verify low pressure in the large tube above the atmosphere. This is accomplished by shutting off cock *n* and opening cock *P*, first removing the rubber tube from the top end of column, the amount attained in this auxiliary apparatus being in round numbers 15 pounds on the square inch, or a trifle in excess of the atmospheric pressure.

THE VALUE OF PROFESSIONAL CERTIFICATES.

AMERICAN engineers are often accused of lending their name as to the value of some patent boiler or mechanical device, but if what *Industries*, of London, says is all true, we must congratulate ourselves on our freedom from the practice of some eminent English engineers. In a recent article the journal mentioned says :

It has been said that in industrial progress the sweat of the brow is lessened by the conception of the brain, and it is true that at the present time more than at any previous period the welfare of the nation depends on the applications of science to the manufactures of the country. In every branch of technology the process of manufacture is dependent on scientific research, and is controlled and improved by the manufacturer, who avails himself of the aid of the technical expert. This expert has trained himself to be quick at devising means by which his knowledge may be rendered useful to others. The improvement in the material produced resulting from the utilization of this knowledge is made known, partly through the press, and partly by the manufacturer seeking the aid of the professional man to describe the nature of the improvement to the general public. The dependency of national progress on the extension and application of scientific knowledge is thus admitted on all sides, and it seems, therefore, the bounden duty of those societies which represent the progress of science to guarantee, as far as possible, that nothing in the name of science shall be used by the adventurer to mislead or deceive the public. From the Royal Society downward, this duty seems at the present time to be of paramount importance, and we are glad to notice that the younger professional societies are beginning to realize their responsibility to the public in this respect. The older scientific societies, even including the Royal Society, in proportion as the work of their Fellows be-

comes of public utility, likewise have the same responsibility.

At the present day, when it is a matter of frequent occurrence for a fellow of the Royal Society to appear and give evidence in the witness-box, and receive a proportionately high fee because he is a Fellow of the Royal Society, it seems essential that the society to which he belongs should adopt a course such as that we have indicated. If this is true of the Royal Society, it is equally urgent that the younger and smaller scientific and professional societies should take steps to counteract the evil arising out of unprofessional acts. The medical profession, which from its nature has always been intimately related to the public, has in all countries made provision that the public should have a perpetual guarantee that its members are generally qualified to perform the work expected from them, and that unprofessional conduct carries with it the penalties of ostracism, and in some cases of prosecution. In some countries the quack is indicted either on information of a public medical officer, amongst whose duties it is to watch trespassers upon medical practice, or sometimes through the spontaneous act of the authorities. The medical profession, in short, determines that its members shall work by a fixed code of ethics under penalty of withdrawal of license.

We now urge some like control on the part of the more modern professions —as, for example, those of the engineer, surveyor, electrician, and chemist—as exists in that of medicine, in all cases involving questions of public faith. On a previous occasion, in connection with the Institute of Chemistry, we urged that a qualification to practice should only be given to those bodies who are prepared to imitate the medical profession in controlling the professional public work of its members. Perhaps, next to medicine, the applications of chemistry attract, at the present time, more public notice than other branches of technical knowledge, and we shall be pleased to learn that the Council of the Institute of Chemistry have recognized their responsibility toward the public by formulating a code of professional conduct which may effectually stop the evils which arise when swindlers, fanatics, and humbugs are let loose on a credulous public without any control. A preliminary meeting to discuss the ethics of professional certificates was recently held in London by the Institute of Chemistry, but, being of an informal character and poorly attended, no resolutions were arrived at as to the attitude that the institute intends to take up on this matter, which is of great importance to the public, if a certificate of the composition or nature of any product can be given by a Fellow of the institute, and such statement can be used by the manufacturer as a recommendation of his wares. Unfortunately, at the present time, the institute has refrained from taking any steps to mitigate the evils which arise in this connection from laudatory and misleading certificates emanating from quacks, and from laudatory and misleading certificates emanating from certain of its own Fellows. The institute has been fortunate in obtaining a charter and constitution which enable it to cope with these two evils. In the preamble to its charter, its functions are defined as the elevation of the profession of consulting and analytical chemistry, and the promotion of the efficiency and usefulness of persons practicing the same, by compelling the observance of strict rules of membership, and by setting up a high standard of scientific and practical proficiency. It is obviously the external duty of the institute, if it wishes to live up to its charter,—which is the elevation of the profession of consulting and analytical chemistry,—to publicly denounce the laudatory certificates and trade puffs which purport to be analytical certificates emanating from Fellows of the institute, Fellows of the Chemical Society, or fellows of no society. The institute should not only publicly denounce misleading certificates, and warn the public against putting faith in certain trade puffs, but it should deal summarily with offenders amongst its own Fellows. The censors already appointed by the institute from year to year might do much in this direction, by framing a code of professional ethics, infringements of which should be punished by censure or expulsion from the institute.

STEAM-PUMPS FOR FIRE PROTECTION.

By Louis R. Alburger, Member A.S.M.E.

IT is a matter of common observation that fire-extinguishing apparatus often proves ineffectual or useless just at the time it is most urgently needed for service. It is also noticed that the failures at such critical times are frequently due to causes which have been overlooked, or considered to be of so little importance as hardly to be worthy of attention.

Few individuals who provide fire apparatus for the safety of their factories and mill property ever believe that a fire will occur to necessitate its use. Latterly, however, factory insurance has come more and more into the hands of large companies and they have given careful attention to fire protection and to apparatus necessary to suppress a fire should it occur. This work has been carried on by able men, and actual contact with a multitude of varying cases has enabled them to reduce the whole subject almost to a science.

No equipment is now considered complete without a steam fire-pump in addition to water-supply tanks and reservoirs, and it is this part in particular that I now wish to consider. It has been customary for the insurer to purchase the steam-pump himself, relying almost always upon the statements of the manufacturers in regard to the questions of proper size, proportions, design, and workmanship, which are sure to arise, when there are wide differences (as is usually the case) in the prices asked by the several bidders. As the ordinary purchaser is not an expert in matters of engineering, it will readily be understood that pumps are often purchased that are quite inadequate for the service, light in construction and lacking those details that are essential to make the apparatus reliable.

The Associated Factory Mutal Insurance Companies became convinced that it would be greatly to the advantage of their insurers if something could be done to make this part of the apparatus better and more reliable. No one was more conversant with the necessities of the case, or better prepared to undertake this task, than Mr. John R. Freeman, engineer of the associated mutual companies, and to him mainly is due the credit of having brought the "Underwriter fire-pump" to the high standard that it has now attained. His work in this direction was so manifestly valuable and his recommendations of such importance to the interests of the mutual insurers, that at the monthly conference of the associated companies, June 15, 1891, the following resolution was passed: "Voted: To recommend that the so-called Underwriter pattern of steam fire-pump, complete with all attachments as per specification of June 1, be recognized as the approved type, and that pumps built and fitted up less perfectly than per this specification be not approved in future installations, except under special circumstances and by special agreement with some executive officer of the insurance companies."

The Underwriter pump is the name adopted to designate the steam fire-pump built in strict accordance with these specifications, and there can be no better way to make the matter plain than to quote freely from them.

"Fire-pumps at the factories which we insure are so very frequently found incapable of being started promptly when tried for our inspectors, particularly at the spring inspection, and are found in so very many cases to be incapable of delivering anywhere near their alleged or rated capacity without violent hammering, as to make it plainly evident that some improvement in fire-pumps is greatly needed at the average mill in one or all three of the following particulars:

"The construction of the pump; the erection and fitting up of the pump; the care of the pump.

"Steam fire-pumps are ordinarily sold, rated, and expected to run at double the speed of a pump for boiler-feeding or any ordinary water-supply.

"Steam fire-pumps do not ordinarily receive such care or attention as a steam-engine or other machine on which the product of the mill depends.

"Being constantly subject to dampness, warmth, and contact with condensed steam, their parts are especially subject to rust.

"After weeks and months of disuse a fire-pump should be capable of being instantly started and run at full speed by a man who is excited and perhaps unskillful.

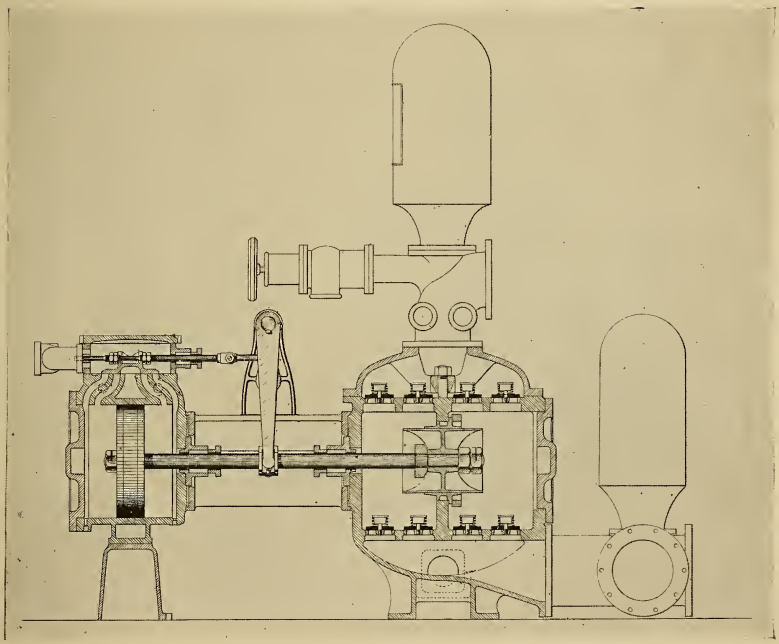
"Therefore a fire-pump needs more strength, better workmanship, and better protection against rust than does a pump for boiler-feeding or ordinary miscellaneous use; and the high speed at which it is expected to run demands the large steam-valve ports and large suction-valve areas specified below.

"Moreover, we regret to find that certain makes of fire-pumps are being introduced in which it looks as though the chief effort was to secure such cheapness of manufacture as would undersell competitors, little attention being apparently given to the above requirements.

"Our inspectors witness tests of two or three thousand fire-pumps each summer, and find so large a number defective, especially after a few years' use, that we have been led to prepare the following specifications:

"These specifications cover only general features of design, and may be viewed as an effort to indicate to those whom we insure the kind and quality of pump we believe is needed.

"On the manufacturer rests the responsibility of first-class workmanship,

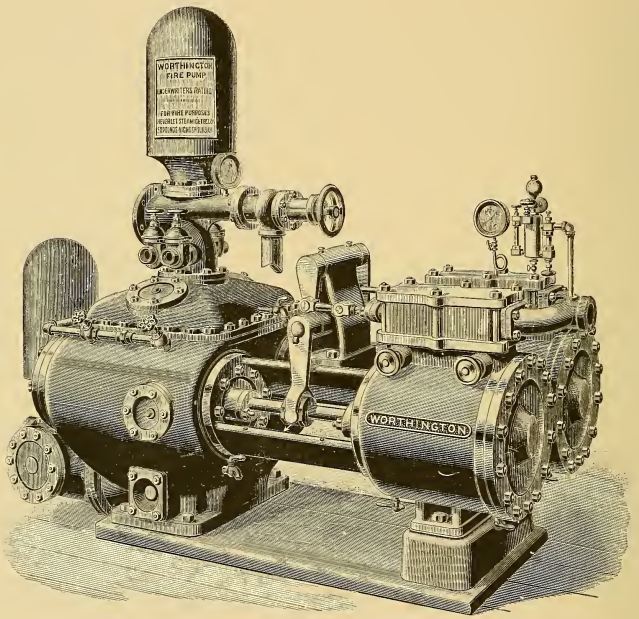


SECTIONAL VIEW OF WORTHINGTON UNDERWRITER PUMP.

material and strength of castings, bolting, etc."

The first question is as to the type of pump best suited, and it is stated that only duplex pumps are acceptable ; this being based upon experience which shows that duplex pumps are more certain to start after long disuse. Of course, it is understood by "duplex pump" is meant that type in which two steam cylinders and two water cylinders are located side by side and the piston-rod of each pump, through the intervening-valve motion, operates the steam-valve of the other pump. The whole power of either steam cylinder is thus available to move a corroded steam-valve or valve-rod, whereas in the single cylinder pump with steam thrown valve, actuated by small supplemental piston, no such surplus of power is available.

Careful attention is given to the diameter and ratio of cylinders and the speed at which fire-pumps should be run. The controlling idea is, that "it is all right to run fire-pumps at the highest speed that is possible without violent jar or hammering within the cylinders." In order that the speed may be high, the water-ways into the pump, the area through the valves, and all the passages in the interior of the water end of the pump are to be of such size that the velocity of the water shall never exceed a speed that is quite moderate.



WORTHINGTON UNDERWRITER PUMP.

Definite instructions are given as to the proper size of the several pipe-openings, and the dimensions of the air and vacuum chambers. Thorough experiments have been made by Mr. Freeman to determine the quantity of confined air, and hence the size of air chamber that is necessary to allow a delivery through lines of hose without undue pulsations. This point is a very important one, as instances have occurred

in which linen hose, in situations where it happened to rest upon rough places or projections, has been worn through in a few minutes' time by throbs or fluctuations in the flow of the water.

The illustrations on the two preceding pages represent the Underwriter pump as built by Henry R. Worthington, and an examination of the engravings will show the distinguishing features of this type of machine. The piston-rods and valve-stems are of Tobin bronze, and, as will be observed, are unusually heavy and substantial, and those parts of the stuffing boxes with which they come in contact are bushed with brass. The water-plungers and the rings through which they run are of special composition. The water-valve seats, plates, guards, and springs are also of composition and the valves themselves are of rubber. It is fitted with cushion valves to regulate the length of the stroke of the pistons, and the handles of these valves are very plainly marked to indicate the direction in which they are to be turned. A pointer attached to the piston-rod enables the engineer to tell at a glance the length of the stroke that the pump is making.

Steam- and water-pressure gages and a safety relief-valve of standard manufacture are furnished, the latter of such size that in case a hose should become kinked or obstructed in any way the water would find an outlet through it without causing a rupture to the hose, such as might arise from too high a water-pressure. A set of brass priming pipes complete with all the necessary valves is attached to the pump and ready for connection with the priming tank. The proper number of 2½′ straight-way hose-valves ready for the hose connections are suitably arranged and attached to the delivery elbow of the pump.

The tests of strength and of speed before acceptance are quite rigid and demand the very best design and construction. The pumps are to withstand a pressure of 300 pounds to the square inch and must be able to maintain a water-pressure of 100 pounds per square inch with a steam-pressure not greater than 50 pounds.

The general satisfaction with the behavior and completeness of the Underwriter pump, as expressed by those who have added it to their plants, seems to be proof of its success. Insurers in companies other than the Associated Mutuals appear quite ready to profit by this good work, and there is no doubt but that in the future Underwriter fire-pumps will be installed by all those who really desire the very best protection against fire.

THE ARTIST TO THE ENGINEER.

THE mother of all progress, Discontent,
Did first bestow the steadfast vision clear
Of present evil to improvement bent
Alike on artist and on engineer.

True servants of the world, twin brothers they;
One bringeth knowledge of earth's loveliness,
And yet that he is greater who would say
Than he who earth with health and wealth doth bless.

To him the river's rippling waters shine,
That in her shoals his bridges' piers may stand;
No worshiper at Lady Beauty's shrine,
He clasps great Usefulness', her brother's, hand.

Unto humanity the faithful friend,
He raised the weight that need had bound so fast
From shoulders bent with toil that had no end
And on the senseless steel the burden cast.

The mighty civilizer, he unites
The severed continents; his monster slaves
Speed o'er the desert sands a line of lights,
Or gnaw to foam the erst unconquered waves.

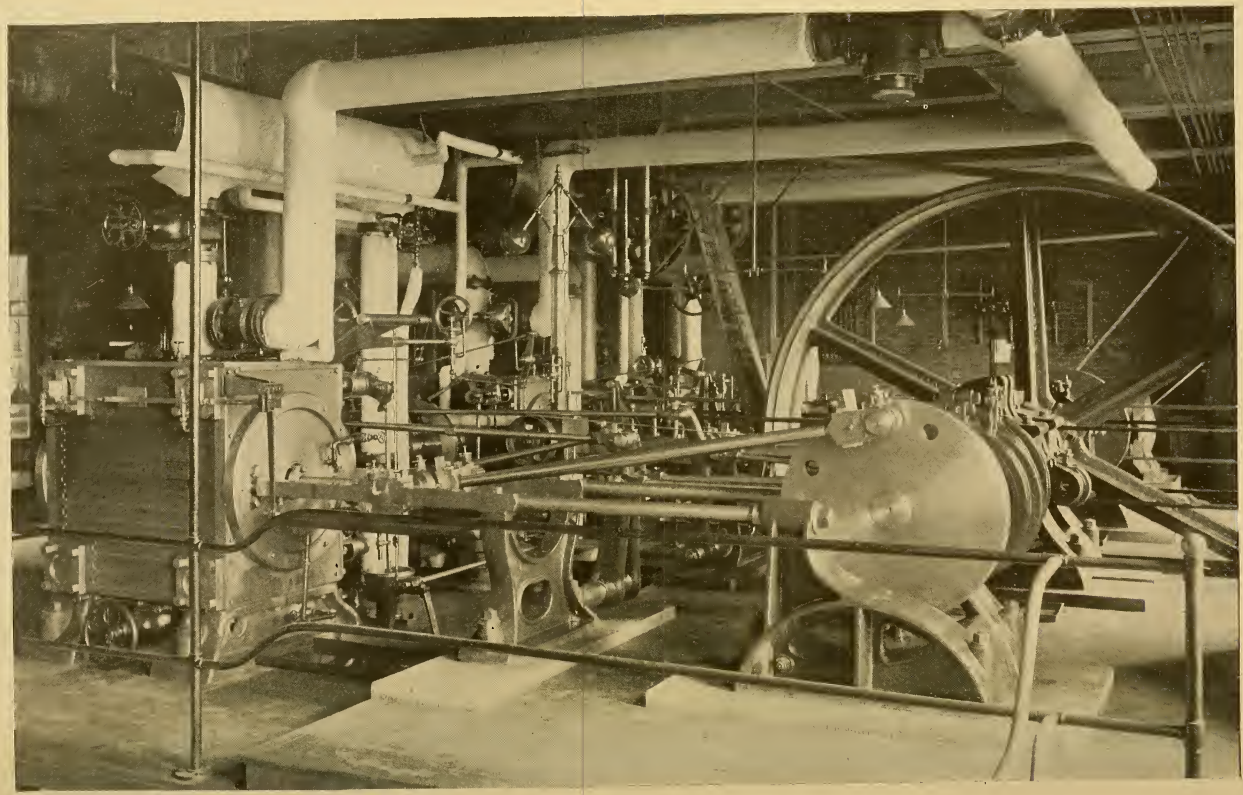
Into the regions of eternal night,
Deep in the close-barred cellars of the ground,
He pierces unafraid and drags to light
The thousand priceless treasures that abound.

That wondrous force, a light without a form,
Which with its strength the vaulted heavens did thrill,
Lo! he has drawn the spirit of the storm
From out the quivering air to do his will.

Through the green twilight of the rocking deep
Where fish sweep by in many a glittering band
And myriad strange and shapeless creatures creep
All silent passes thought from land to land.

Thou engineer, who to the earth hast given
A higher life, more happy, full, and free,
Go forth! A golden day dawns in the heaven
And greater triumphs surely wait for thee!

SARA KING WILEY.



TRIPLE-EXPANSION EXPERIMENTAL ENGINE AT THE LABORATORIES OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON, MASS.

A TRIPLE-EXPANSION EXPERIMENTAL ENGINE.*

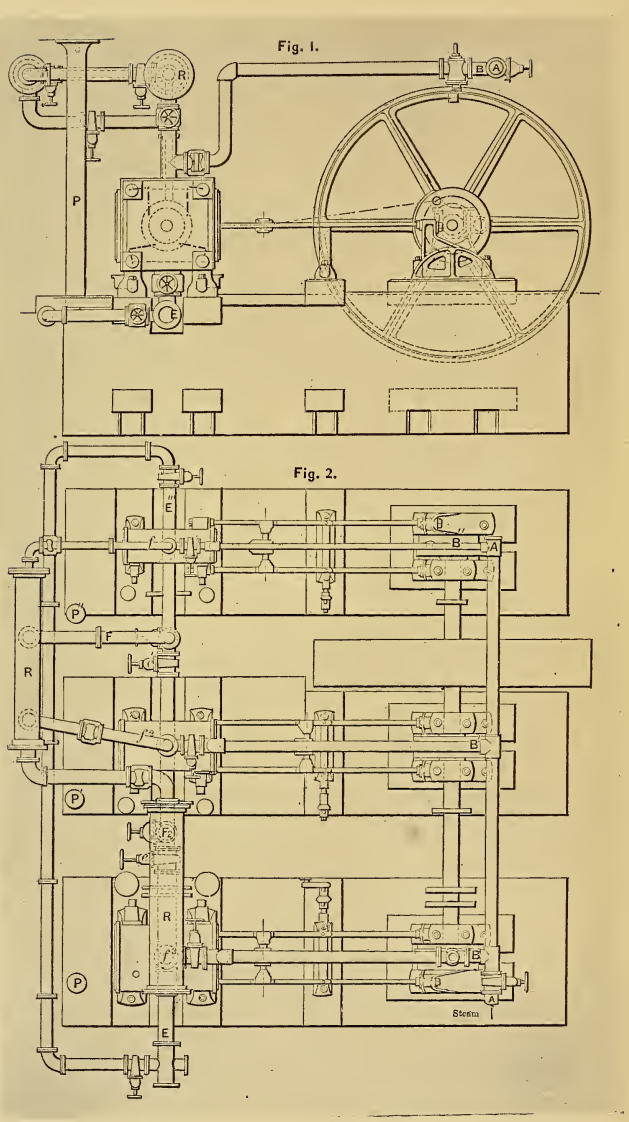
By Cecil H. Peabody, S.B.

ONE of the most important pieces of apparatus found in the engineering laboratories is the triple-expansion experimental engine, built by the E. P. Allis Company, of Milwaukee, Wis. The engine is of the Corliss type, and has three cranks arranged as shown by Figs. 1 and 2. The diameter of the high-pressure cylinder is 9 inches; of the intermediate cylinder, 16 inches; and of the low-pressure cylinder, 24 inches; the stroke of each is 30 inches. Each cylinder is steam-jacketed on the heads and barrel, and steam may be applied directly to any or all of the cylinders; so that by proper combinations of piping and valves the engine may be run simple, compound, or triple. The intermediate receivers are also provided with steam jackets, so that they may act as reheaters. The exhaust steam is received and condensed by a surface condenser of the marine type, which drains into an independent direct-acting air-pump. The condensed water from the air-pump is collected and weighed in tanks on scales, covered to avoid surface evaporation. The several jackets on the cylinders and intermediate receivers, five in all, are drained into separate receivers made of 5-ft. sections of 8-in. pipe, closed at the ends and provided with glass water-tubes and scales, so that the condensed water may be collected and measured. Provision is made for applying the indicators, gages, and thermometers required for making a complete thermodynamic test of the engine. The cylinders, receivers, and piping are thoroughly wrapped with asbestos paper, hair felt, and lagging, or canvas.

The engine is belted to the main line of shafting running through the middle of the laboratory, and provides power for lighting the entire building by electricity, and for various tests requiring power. There are now in the laboratory, the dynamo, which absorbs about 50 horse power; two water-cooled friction-brakes that can absorb 50 horse power each; rotary and centrifugal pumps, and other apparatus requiring power. The short section of shafting which receives the driving-belt can be uncoupled from the line-shafting running each way; considering the friction of this short section with the friction of the engine, the friction of the several lines of shafting and of the brakes when unloaded, and also the load on the dynamo, can be determined by the aid of dynamometers, and thus the load on the engine may be determined, and also the friction of the engine.

Figs. 1 and 2 give an elevation and plan intended to show the general arrangement of the foundations, frames, and the piping. Parts receive the same letters in both figures. The section of the city on which the building is located being made land, the foundation was made by piling over the entire area on which the engine stands, and capping the piles with several courses of large granite blocks. From the granite the engine beds are carried up through a sub-basement, so as to place the engine conveniently with reference to the engine room or basement floor. Each cylinder stands on blocks of cut stone, and is bolted through stones built into the foundation. The engine shaft is carried by splayed cast-iron bearings which are supported and bolted to the foundation in a similar manner. Each cylinder is connected to the shaft-bearings in front of it by wrought-iron rods, to take up the thrust and pull of the piston and connecting-rod. These rods are supported at about mid-length, and, from the support to the cylinder, are square, and act as guides to the cross-head. The fly-wheel is placed between the high and intermediate engines, the location being decided by the fact that it is the common custom to disconnect the low-pressure cylinder, and run the

* Originally printed in the *Technology Quarterly*.



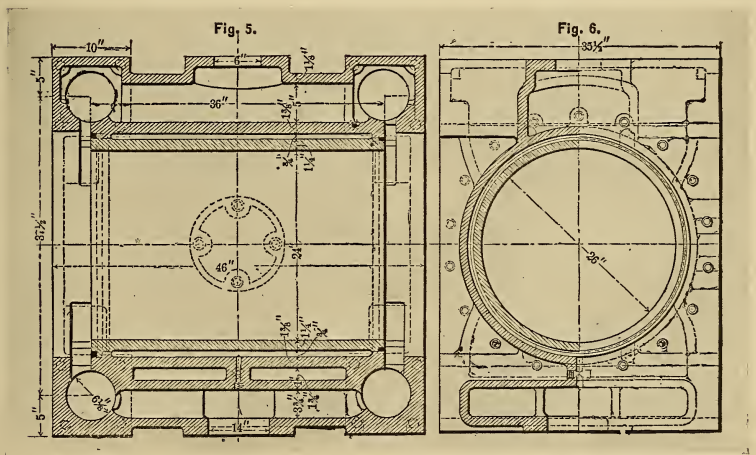
FIGS. 1 AND 2.—ELEVATION AND PLAN VIEW.

high-pressure and intermediate cylinders compound and non-condensing. The cranks for the high- and low-pressure engines are overhung; the intermediate crank is a solid cast-steel crank bolted to flanges on the ends of the two sections of the shaft.

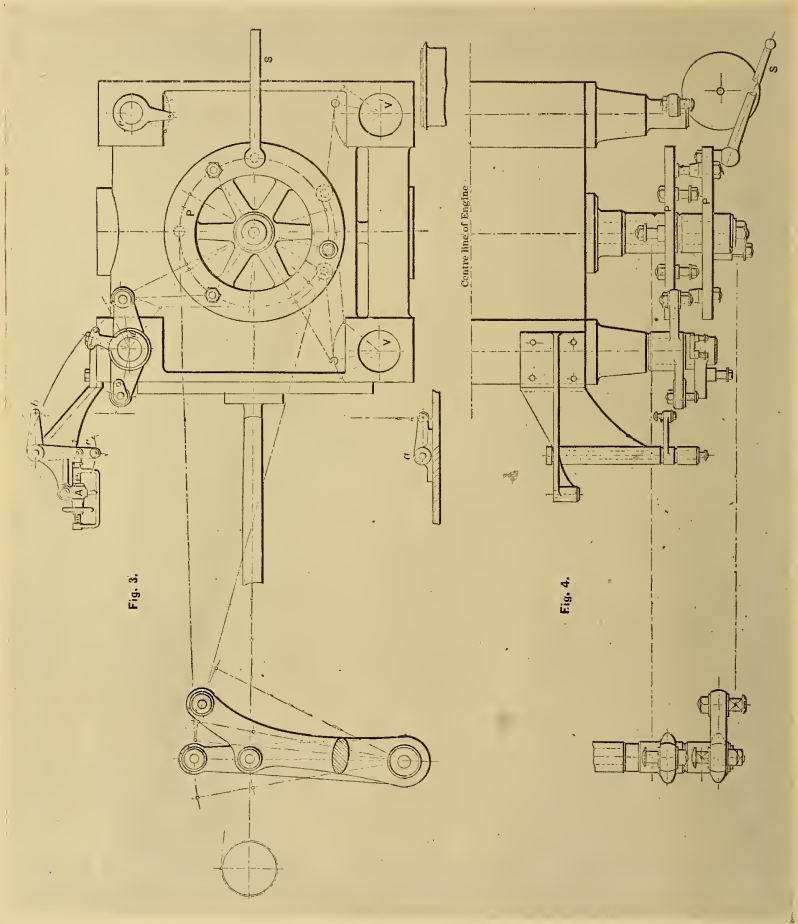
A 6-in. pipe A runs through the laboratory and supplies steam at about 150 lbs. pressure for heating, for various experiments, and for running the engine. At B, B′, and B″ are branches running to the several cylinders, each with a stop-valve near the cylinder for the convenience of the engineer. Near B is a reducing-valve or regulator, for reducing the pressure of steam to 40 lbs. to the square inch or less, when the low-pressure cylinder receives steam direct. R and R′ are the first and second intermediate receivers. R′ is set over beyond the columns P′, P″, to make room for the driving-belt. An exhaust-pipe E runs under all the cylinders, and into this each cylinder may be directly exhausted. Stop-valves e and e' divide the exhaust-pipe into sections when required. A valve under the low-pressure cylinder shuts it off from the exhaust-pipe when the large engine is disconnected.

The high-pressure cylinder may communicate with the intermediate receiver R′ by the pipe f for admission, and by the pipe F for exhaust. The intermediate cylinder communicates with the receiver R′ by the pipe f_2 for admission, and with the receiver R by the pipe F_2 for exhaust. The large cylinder receives steam from the receiver R through the pipe f_3. Finally the two receivers are connected by a pipe with a stop-valve as shown. There is a roundabout exhaust with valves at each end for the high-pressure cylinder. Normally the high-pressure cylinder receives steam from the pipe B″ and exhausts by the pipe F to the receiver R′; the intermediate cylinder receives steam from the receiver R′ by the pipe f_2 and exhausts to the receiver R by the pipe F_2, and the low-pressure cylinder receives steam from the receiver R by the pipe f_3 and exhausts through the valve beneath it into the pipe E.

Among the combinations rendered possible, the following may be noticed. Steam may be supplied through the reducing-valve at B to the low-pressure cylinder and through the receiver R to the receiver R′, and so to the intermediate cylinder; meanwhile the high-press-



FIGS. 5 AND 6.—TRANSVERSE AND LONGITUDINAL SECTION OF LOW-PRESSURE CYLINDER.



FIGS. 3 AND 4.—VALVE-GEAR AND ECCENTRICS.

ure cylinder receives full-pressure steam as usual, and exhausts by the round-about pipe ; all the exhaust steam may be used for heating at about 4 lbs. back-pressure. When a test is to be made, the engine is readily changed to triple-expansion condensing.

The condenser used for experimental work only, is set in a sub-basement, so that the exhaust-pipe drains into it, and it in turn drains into a direct-acting air-pump, from which the condensed water is received in weighing-tanks.

Steam for jacketing the high-pressure cylinder and the first intermediate receiver R′ is taken from the direct supply the pressure on the jackets to be made lower than boiler-pressure when desired. The low-pressure cylinder receives jacket steam from the pipe B before the reducing-valve, and the pipe for this purpose has its own reducing-valve to control the pressure in the jackets. The jackets are designed to carry full boiler-pressure on all the cylinders when desired.

The drainage from the three jackets (*i.e.*, the barrels and two heads) of each of the cylinders is collected and led directly under the pressure in the steam-jackets to three measuring-vessels in the sub-basement. The drainage from the receiver-jackets is similarly disposed of.

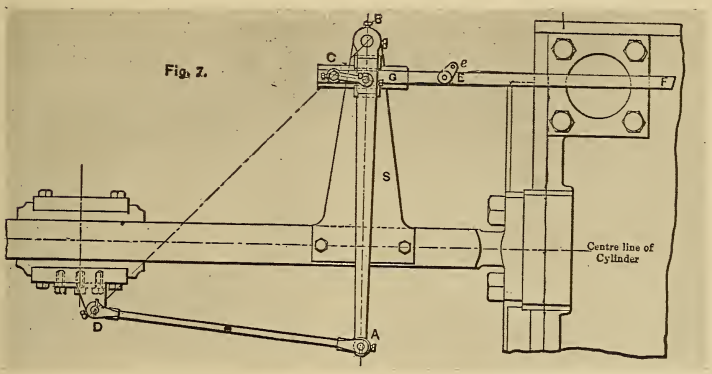


FIG. 7.—INDICATOR MOTION FOR INTERMEDIATE CYLINDER.

of steam to the high pressure cylinder by a ¾-in. pipe ; this pipe has two branches, one to the receiver and the other to the cylinder. The ¾ in. branch-pipe leading to the cylinder is again branched into three parts, one to the barrel and one to each of the heads ; each of the three jackets has a pet-cock to discharge the air when the jackets are supplied with steam, and to reveal leakage of steam when the valves are shut. Thus the barrel or the heads, or both, may be jacketed with steam.

The intermediate cylinder and second receiver R are supplied with jacket steam through a ¾ in. pipe from the steam pipe B′ leading to the intermediate cylinder ; a reducing-valve allows

When the receiver-jackets are not in use the receivers themselves are drained into the measuring-vessels, and an arrangement of two valves with pet-cock between makes it sure that the drainage comes from the jackets or from the receivers, as the case may be, and reveals leakage should it occur.

With the large number of large valves it is apparent that some method of detecting leakage must be devised if the tests on the engine are to receive credence. The valves are of a good type, are new, and have been carefully handled to avoid injury. Some of them may be tested for leakage while the engine is running, others can be shut and tested for leakage before the engine is started.

To arrange for starting the engine a one-inch by-pass is carried round the stop-valves of the intermediate and low-pressure cylinders. The by-pass pipe has two valves, and on the space between is a pet-cock that can be used to test for leakage of the valve on the by-pass pipe, or for leakage past the stop-valve into the steam-chest.

The three cylinders of the engine have valve-gears of the Corliss type; those of the high and intermediate cylinders are arranged as usual and are moved by an eccentric acting on a wrist-plate. Vacuum dash-pots insure a rapid and quiet closing of the admission valves. Since the low-pressure cylinder has a volume somewhat more than twice that of the intermediate cylinder, a special valve-gear with two eccentrics is arranged as shown by Figs. 3 and 4. The wrist-plate P is moved by an eccentric with a little angular advance, suitable for giving release and compression, and is connected to the exhaust-valves at V and V_1 in the usual manner. The wrist-plate P_1, outside of P, receives motion from an eccentric with a large negative, angular advance, and the admission-valves are given a large lead when in mid-position in compensation. Thus the release mechanism may be arranged to give a cut-off longer than half-stroke, as the proportions of the cylinder require.

The governor is attached to the frame of the intermediate cylinder, and, by the aid of a horizontal shaft running in front of the three cylinders, may control the releasing mechanism of each of the cylinders. In Fig. 4, *a* is the horizontal shaft controlled by the governor. A vertical link acts on the arm *b* of a bell-crank lever above the cylinder, and from another arm *c* a link is carried to the collar *d* on the crank and valve-spindle and from thence to a collar *e* on the head- and valve-spindle. When desired, the governor may be disconnected by dropping the link from *a* to *b*, and the disengagement gear may then be set by hand while the engine is running, by aid of the hand-wheel and screw at A; of course the hand adjustment is thrown out of gear when the governor has control of the releasing-gear. At S is a starting-bar for moving the admission-valves by hand, when the gab-rod is disconnected for the admission wrist-plate.

Figs. 5 and 6 give transverse and longitudinal sections of the large or low-pressure cylinder. The barrel jacket is made by bushing the cylinder-casting, as shown, the bushing being forced in under hydraulic pressure, and made tight by a ring of copper driven into a dovetail groove. The ends of the cylinders are jacketed by coring out the cylinder-heads.

The indicator motion for the intermediate cylinder is shown by Fig. 7. S is a standard bolted to the engine frame near the crank-end cylinder-head. A, B is a swinging lever, connected by the link A, D to the engine cross-head, and by the parallel link C, G to the rod E, F.

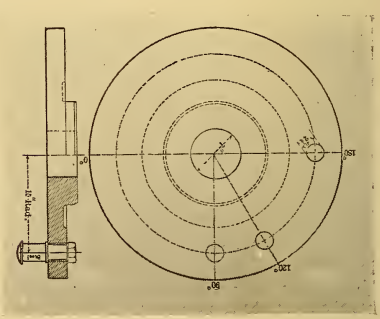


FIG. 8.

The rod E, F slides in guides, one on the standard S as shown, and the other on the head end valve bonnet at the right hand, and it is at the proper height for the indicator-cord. The crank-end indicator-cord is hooked directly on to the pin *e*, which is on an arm E *e*, that can be swung up or down to give a small vertical adjustment, and clamped by a thumbscrew. The other indicator has a similar arrangement. All the joints of the indicator motion have split brass bushings and set screws to take up lost motion. When worn out the bushings can be renewed. Thus at A the link is forked, and embraces the end of the lever A, B; the pin is fast in the fork, and turns in a brass bushing in the end of the lever, with a set screw near A.

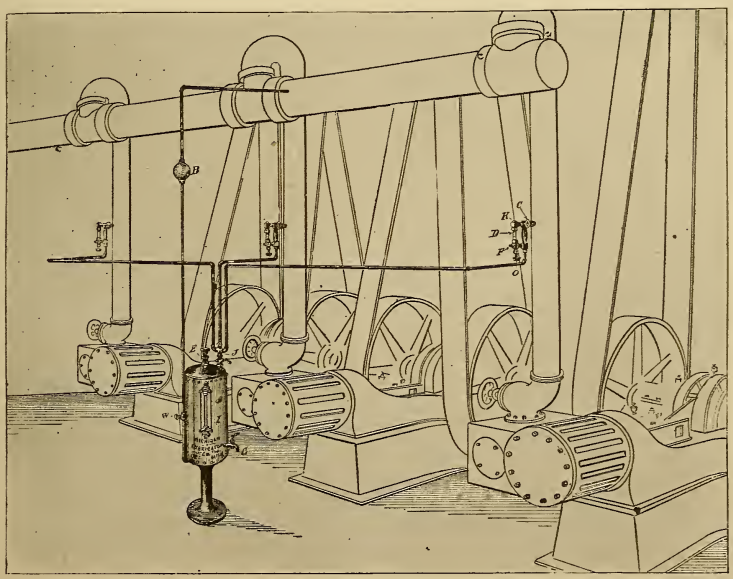
The angles at which the several cranks follow can be arranged by a device shown in Fig. 8. The disc has three distinct holes bored in it, making angles of 90°, 120°, and 180°. The steel crank-pin is made tapering, and fits into a tapering steel bushing that is cut in two at one side, and part way through at seven other places. A heavy hexagonal nut on the back of the disc draws the crank-pin in till its collar bears on the face of the disc, and at the same time forces the taper bushing in, and secures the pin in the disc. This device has been found to work well on this engine, which develops about 150 horse-power, or 50 horse-power on each crank when running triple with 150 lbs. steam pressure and at 80 revolutions per minute.

A UNIVERSAL LUBRICATOR.

AMONG the valuable new devices recently brought out is a lubricator arranged for use on any number of engines. From the engraving shown on this page it will be seen that a number of pipes are attached to a central reservoir and the sight-feeds are placed on the steam-pipe in the same manner as ordinary lubricators are.

The number of drops to be fed to cylinders is regulated at the sight-feed glasses by valves which can be independently closed when the engines are not running.

The tank for holding the oil can of course be made of any desired capacity, although the largest which has been constructed so far is one for 100 gallons.



This arrangement for lubricating engines will prove very convenient for the engineer who is in charge of a number of engines located in one room. The manufacturers are the Michigan Lubricator Company, Detroit, Mich.

THE PRODUCTION OF ALUMINUM.—II.

By E. P. Allen.

BY the Cowles process aluminum unalloyed cannot be made ; for that reason it has formed no part of the previous article. It has been mentioned that Héroult is also patentee of a process identical with that of the Cowles. We will call this the electro-thermic process for producing aluminum alloys, not by any means because it has been determined whether the process is electro-thermic or electrolytic, or both, for that matter, but because the patentees have considered it to be electro-thermic, and the preponderance of evidence seems to make in that direction. Alumina (when not in solution as in the fluoride process) is so refractory as to be melted only in an oxyhydrogen flame, and it is so stable a compound that no attempts to reduce it by carbon have been successful at any temperature obtainable by ordinary modes of combustion. It occurred to the Cowles brothers and to Héroult to see what effect carbon might have under the heat of the electric ore, and therein lies the whole process. As early as 1807, Sir Humphrey Davy attempted to reduce alumina, as he did soda, by the electric current, but whether it was because his current was not sufficiently powerful, or that he did not attempt to reduce in the presence of carbon, he succeeded only in fusing the oxide. His experiment was probably solely in the direction of electrolysis.

The outcome of the experiments of the Cowles brothers was a furnace in which their process could be carried out. On the strength of it the Cowles Electric Smelting and Aluminum Company was formed in Cleveland, O., and works were established at Lockport, N. Y., deriving power from the waste water of the Erie Canal. Some 700 H.P. were utilized. The practically simultaneous invention of Héroult's in this field is utilized also at Newhausen. The furnaces used are of two types, horizontal and upright. The horizontal furnace is a long box-like structure, built of firebrick or iron, and lined thickly with carbon, the bottom being provided with a sump. At each end is a hole for the insertion of the electrodes. The upright furnace is a short cylinder in shape, constructed of similar materials, but in its case one electrode is inserted through the top and the other through the side, near the bottom. On the opposite side from this lower electrode is a tap-hole. The process is not continuous, but is made practically so, so far as the electricity is concerned, by switching the current from one furnace to another while the former is being emptied and recharged. The electrodes, in their latest development, are huge carbon cylinders, five feet in length by eight inches in diameter. The alloys made by this process are aluminum bronzes (*i.e.*, aluminum and copper) and ferro-aluminum. It may be remarked, by the way, that by the reduction of the oxides of silicon and of manganese siliconized copper and manganized copper are also made in these furnaces, but these alloys have little to do with the subject of aluminum. It is, of course, not by preference that only alloys are obtained from the Cowles process ; it happens that at the great heat at the electric arc aluminum would no sooner be separated from oxygen than it would recombine with oxygen if some provision in the shape of another metal were not made to receive and hold it. This the other metal can do only by forming an alloy with the aluminum. For this reason, together with the alumina and carbon, finely-divided copper or iron is charged into the furnace in an intimate mixture. When the charge is made, the full force of a current of say 6000 amperes by 60 volts is turned on. What goes on then is not known, but it is known that carbonic acid gas is given off, and at the end of the run an alloy of aluminum with copper or with iron, as the case may be,

remains in the bottom or is tapped out into molds.

There are certain inherent disadvantanges in the process even for making alloys which will result in its abandonment sooner or later, since ferro-aluminum presents no advantages over the unalloyed aluminum in steel practice, where alone it has been of value, and since copper aluminum alloys can be made just as well, indeed much better, by melting the two metals together in a crucible. It is not possible to obtain a given alloy in the electric furnace, that is, an alloy containing a given proportion of aluminum, and the practice has, therefore, been in the case of the bronze to obtain a high alloy, at haphazard so to say, which is afterward reduced to the proportion desired. But the chief difficulties are two. The first is, that alumina when purified from bauxide is obtained as a fine flocculent powder which is totally unsuited to the practice of the electric furnace; the Cowles had their best results from the use of native corundum broken into a uniform walnut size, but this gave them a very impure and often a useless bronze (when the "corundum bronze" was reasonably pure, however, the best results in tensile strength and other qualities were obtained from it). The second difficulty is that the quality of finely divided iron is bad, and the cost of finely-divided copper is great. But even if the process allows the use of copper melted down from pig and held in a molten state in the sump at the furnace, as we gather it does from some publications in regard to the Héroult practice, the extreme heat makes the process wasteful by burning the materials. Finally, the electro-thermic method suffers in comparison with the fluoride process in its discontinuity. So cogent are these facts that it is safe to say no aluminum bronzes have been made in this country by the electro-thermic method since the latter part of 1890.

But to return to the suit of the Cowles against the Pittsburgh Reduction Company. In the electro-thermic method no attempt was ever made to fuse the charge except by electrical energy, and as the Cowles brothers did this as early as 1885, they claim prior invention and application of electrical energy to the purpose of fusing ores preparatory to reduction. According to this, the initial feature of the present successful practice in the fluoride process—and without which, as has been mentioned, the fluoride process has no success—belongs to the Messrs. Cowles. This is an immense claim to make, and when first announced met with some lifting of eyebrows. Yet it is sufficiently important to demand serious consideration and rebuttal. Of the Siemens furnace which is quoted against the claim, it must be said that it was constructed for the purpose of melting, not ores for reduction, but metallic iron. Whether, however, the claim is patentable at all, and more than this, whether it is contained in the Cowles patent or not, is now a question for the courts to decide. If this universal claim is in the Cowles patents, it is there but obscurely, and it would seem that the Messrs. Cowles hardly realized its importance in its application to all processes for the electrolysis of fused masses when they drew up their specifications and claims for the Patent Office.

Besides the electro-thermic processes as practiced in Lockport, N. Y., and in Neuheusen, Switzerland, there is a modification of it recently put in operation by the Willson Aluminum Company on water-power at Leaksville, N. C. Mr. Willson is the patentee, and his modification consists in the use of monoxide as the reducing agent instead of carbon. The gas is introduced through the electrode, the latter being made with a two-inch bore for the purpose. In other respects the process and the apparatus are similar in principle to those of the Messrs. Cowles and Héroult.

We have now covered in a manner the field of the production of aluminum and of its alloys, so far as they are produced directly, but as the materials of production are important elements therein, some consideration is due to them.

Cryolite, a native double fluoride of aluminum and sodium, has heretofore been found in quantity only in Greenland. Some specimens from Arkansas have shown a very good appearance, but it is a question whether there is any quantity to be found there. The Green-

land supply is controlled by a syndicate of salt manufacturers, the American member of which is the Pennsylvania Salt Manufacturing Company of Philadelphia, with works near that city, and also at Natrona, on the Allegheny. Here the cryolite is treated for the conversion of the sodium fluoride contained into sodium chloride, *i.e.*, common salt. Cryolite can be obtained at first hand only from the company; its price in bulk is placed at 6½ cents and upward. Very little cryolite is used in the aluminum process, since, with proper working, the bath remains constant for an indefinite period, alumina alone being added from time to time. Though a remarkably pure mineral, as minerals go, still on account of its impurities (silica and iron oxides) a pot freshly started does not turn out the purest metal for a day or so. The impurities are reduced gradually by the current and alloy with the first day's metal; thereafter the metal is affected only by such impurities as may be in the alumina and the electrodes; that is to say, if the workmen are careful not to allow contamination by admission of foreign substances.

Alumina being the source of the metal aluminum, is naturally of prime importance. It has been pointed out that the purity of the metallic product depends upon the purity of the materials of production. Whatever impurities go into the pot are ladled out in the metal. Aluminum is most difficult to refine; for all that has been achieved so far, in spite of various attractive advertisements and prospectuses, we may say that it is impossible to refine. A small amount of iron forms an alloy which it is impossible to separate by liquation, while silicon has too nearly the same specific gravity as aluminum; and both possess too nearly the same affinities as aluminum to be separated by combination with another element. Since, therefore, the fault cannot be cured it must be prevented. It is apparent that no clay, no native mineral whatever, can be used to make aluminum by the fluoride process. A new discovery may make a difference, but that is beyond prophecy at present. If all the owners of clay-beds, of corundum and cyanite, and bauxite, etc., did but realize this, the work of the correspondence clerk in the aluminum offices would be much lightened to good purpose. Since clays rarely contain more than 20 per cent. alumina, equivalent to about 10 per cent. metal, being made up, for the rest, of silica and iron oxides (the natural enemies of pure aluminum) together with the alkaline earths and water, they are not economical sources of aluminum so long as richer ores exist. It profits us very little at present that aluminum is so plentiful as to be everywhere under our feet, except in so far as it fulfills a quite important function where it is, since an aluminous earth to live on is more important than an aluminous house to live in. Corundum, frequent in North Carolina, and long known as an emery, is a crystalline hydrate of aluminum of high purity for a native mineral. It has been used without preparatory treatment, except in crushing to proper size, in the Cowles electric furnace. But it is both more expensive and, on account of its hardness, more difficult to manage than its amorphous relative, bauxite. Aluminum is contained in some 200 different minerals, but in bauxite alone does it exist in proportions and conditions suitable to the present state of the aluminum industry. Bauxite was first found in France, near Baux, in the department of Arles, whence its name. It is a hydrate containing from 50 to 70 per cent. alumina, 40 to 90 per cent. water, and impurities in the shape of silica and iron oxide. Bauxite containing no iron is white, and is thus to be distinguished from kaolin, with which it is often confounded, only by the fact that it is not, like kaolin, a uniform agglomerated powder, so to say, but contains throughout its mass numberless series of small concentric spheres. From white, the color of bauxite varies to a deep red according to the content of iron. The red bauxites containing most iron oxides have at the same time least silica, and as, by the process of purification in use in Germany, iron oxides are less difficult to separate than silica, or, rather, are separable at less expense, these red bauxites, such as are the common French variety, have been preferred. Alumina has a strong affinity for textile tissue and

for coloring-matter and has in consequence found an important use as a binder in dye-works. The body of the color known as *lakes* is alumina. For this purpose alumina has long been manufactured in Germany in the Chemische Fabrik of Bergius, at Goldschmieden, near Lissa, in Silesia. There are a number of methods of purification known; that employed by Bergius is carefully guarded at his works, but it is doubtful whether there is anything more to guard than the manipulation. The alumina turned out contained, until little over a year ago, never less than 1.5 per cent. impurities, but as the demand grew in the aluminum industry, Bergius increased his plant and improved his process so far as that now he is able to turn out a product containing not more than 0.40 per cent. silica and iron oxides, from which aluminum with an average fineness above 99.25 may be produced. The alumina is shipped in the anhydrous state; that is to say, it is thoroughly calcined before shipping, and, in spite of the great hygroscopicity of alumina, the product of Bergius's works seems to take up very little water in transit. Bergius, for the most part, uses the French bauxites.

Until recently the only alumina manufactured in this country has been turned out as a by-product of salt manufacture from cryolite by the Pennsylvania Salt Manufacturing Company. As the sodium fluoride of cryolite is converted into the chloride, aluminum fluoride is left in the form of oxide. This alumina has been largely used by the Pittsburgh Reduction Company, but it is even less pure than the earlier, lower grade manufactured by Bergius, and at the same time more expensive. Large deposits of high-grade bauxites are to be found on and about the line between Northwestern Georgia and Northeastern Alabama, whence they have for some time been shipped for use in furnace linings; its high refractory quality of alumina has been alluded to. It was, of course, but a matter of time before some amongst our own people should take hold of the alumina industry and utilize our own bauxites, thus saving the cost of the long transhipments from Germany. Accordingly, in July last, the Solvay Process Company, of Syracuse, N. Y., manufacturers of soda by the Solvay or ammonia process, commenced to manufacture alumina also. The conjunction of the latter industry with the former is conducive of economy, owing to the fact that soda-ash (with which, as an initial step, bauxite is treated to form a soluble aluminate of soda) is a product in the manufacture of soda. The price at which alumina, pure and anhydrous, is now furnished is in the neighborhood of seven cents per pound, in ten-ton lots. Bauxite is delivered in New York or Pennsylvania at nine to ten dollars per ton by the carload, but the process of purification is expensive. The product of the Solvay Process Company contains some 2 per cent. of soda, but this is a small matter, since the sodium when reduced by the current is at once burned and cannot contaminate the aluminum.

The development in the manufacture of carbon electrodes for electrolysis has been great since the advent of the aluminum industry. At its commencement bundles of arc-light carbons had to be used, and in the Cowles furnace bundles of long carbon plates of inferior density, which gave much trouble by cracking and breaking under unequal heating. New apparatus was devised, however, and now both the three-inch and eight-inch cylinders are "squirted," *i.e.*, passed through a die under a pressure of 400 tons and upward. They are then subjected to a high heat for ten to fourteen days, to ensure complete expulsion of moisture. When oxygen is released in the fluoride process, whether by direct reduction of the alumina or of the latter conversion to aluminum fluoride prior to reduction, it is released at the positive pole, *i.e.*, at the carbon plugs, and then the plugs are consumed. Whatever impurities (silica and iron oxides) they contain goes into the bath and thence into the aluminum. Thus the carbons are another source of impurities, and the quality of them is a grave matter, since in round numbers about 1 pound of carbon is consumed per pound of metal produced. To the Solar Carbon Company of Pittsburgh belongs the credit of having thus far produced the most durable carbons under the heat to which they are subjected in electrolytic work, and the

purest carbons as well, containing often as low as 0.20 per cent. ash. Several other carbon manufacturers are preparing to make competition. At present the best price for finished electrodes is about four cents per pound.

From the figures given above in connection with the materials, some computation of the cost of producing aluminum may be made. Naturally, if, or when, the demand for aluminum increases so far as to warrant the establishment of a "ten-ton plant" (*i.e.*, producing ten tons per day), it may be economy to put up works in connection for the manufacture of alumina, and carbon electrodes, and the cost of materials may be lessened thereby, but under present conditions the figures sometimes given by enthusiastic votaries of the shrine of aluminum seem utopian. At present we may reckon the materials at

1 pound carbon per pound aluminum...	4c.
2 pounds alumina per " " ...	14c.
cryolite " " " (say)	1c.
Total.....	19c.

Thus we have 19 cents for bare cost of materials; the labor certainly cannot be counted at less than 5 cents per pound (this figure is given impliedly as a minimum by Captain Hunt, of the Pittsburgh Reduction Company), which makes 24 cents; the power, again, cannot be less than 5 cents, which makes 29 cents; and there is all the expense of plant and administration besides. These are not guesses of the present nor dreams of the future, but facts, *i.e.*, things already done. Much is said of the probability that aluminum will sooner or later oust steel and iron; laying aside the fact of the physical ability of aluminum to perform the work of steel and iron, the bare matter of cost is prohibitive, and what is more, it will always be prohibitive. Iron is reduced from an oxide, as well as aluminum, but oxygen has so much stronger affinity for aluminum than for iron that it takes, one may say, an infinitely greater energy to separate the two, and energy, *alias* power, costs money. Bulk for bulk, because of the difference in specific gravity, aluminum may some day be produced more cheaply than copper, as it is already produced more cheaply than tin (or, more accurately, has been sold at a lower price). But it is extremely doubtful whether it will ever advance beyond competition with copper, tin, and antimony. Even zinc and lead are out of its reach, much more so iron and steel. The present total capacity of aluminum works in this country now in operation (viz: those of the Pittsburgh Reduction Company and the Cowles Electric Smelting and Aluminum Company) is not greater than 1000 pounds per day. The Boonton works of the United States Aluminium Metal Company are not in operation. The Willson Aluminum Company, if they have commenced to work on alloys, have done so only on an experimental scale. There are no other producers in this country.

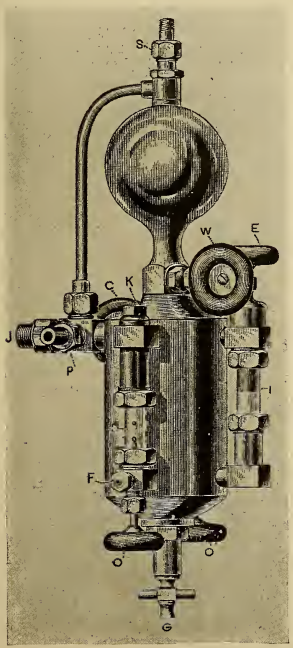
In England the Metal Reduction Syndicate has a capacity of some 400 pounds per day, and the Cowles Syndicate Company, Limited, if they persevere in their intention to take up the fluoride process after the example of the Cowles Company here, will have a possible output of 500 pounds per day. The capacity of works operating on the continent of Europe we are less able to state, but it is not in total more than 1500. The grand total for the world is, therefore, in the neighborhood of 3400 pounds per day; but at the recently reigning and unfortunately fluctuating prices it is doubtful whether more than two-thirds of that amount has been consumed.

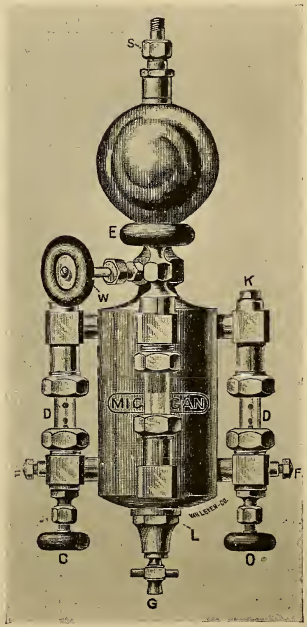
The cost of aluminum will probably decrease more rapidly than that of any other metal in proportion to the increase of output. For with large increase of plant the increase in labor remains small. Under present conditions it is not possible to sell aluminum profitably at a price much below 75 cents per pound. The recent drop to 50 cents was merely a temporary measure. But only very large capital could afford to take advantage of this fact that a large output would mean lower prices and consequently a wider market; only very large capital could afford to turn out two to five tons per day, and sell only half a ton, while waiting for the lower prices to take effect; and the aluminum companies of this country have unfortunately not been blessed with large capital, else,

so far as this increase of plant is concerned, they must be playing a waiting game. In conclusion, it is not too much to say, however, that though aluminum has many uses and will have many more, neither now nor in the future need the producers of any other metal quake in their shoes.

A NEW MULTIPLE-CYLINDER LUBRICATOR.

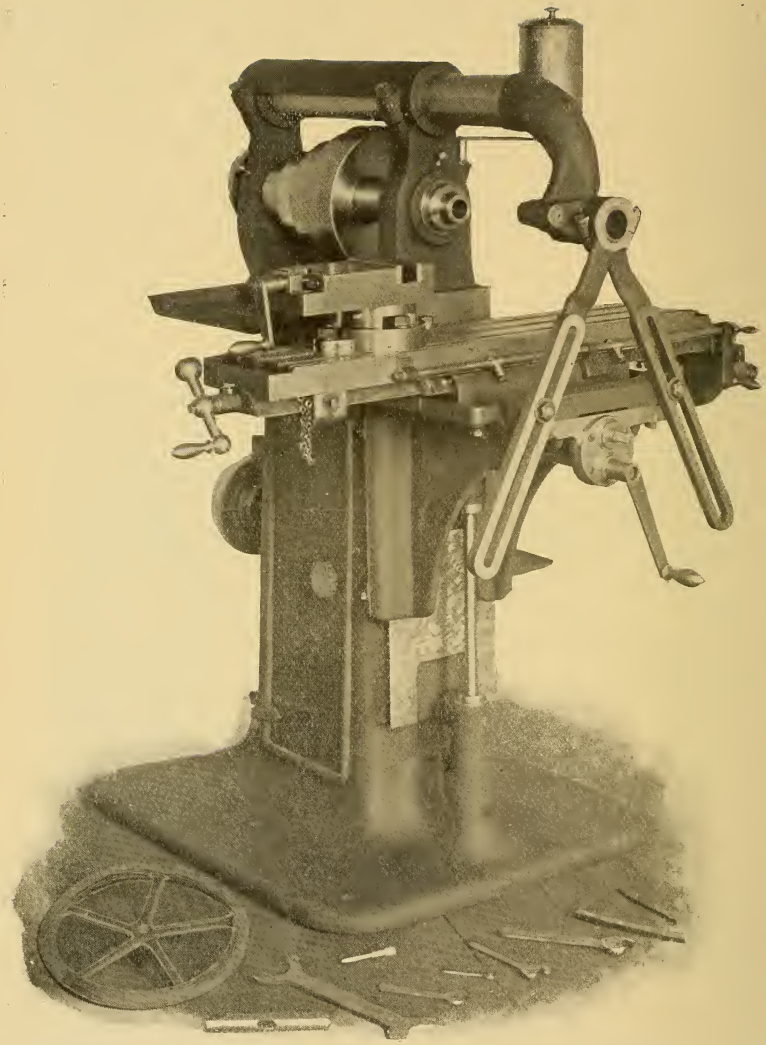
THE Michigan Lubricator Company, of Detroit, Mich., have just put on the market a lubricator for use on compound and triple-expansion engines which oils from one reservoir steam engine cylinders employing various pressures.





Heretofore the difficulty encountered with this class of lubricators was the imperfect lubrication of the low-pressure cylinders, but in these new machines a principle is involved whereby the oil delivered from the multiple sight-feeds is so fed that the tendency to siphon, caused by the low-pressure cylinder, is completely overcome and both cylinders receive regularly the exact amount of oil set to feed; this also applies to engines having vacuum cylinders, and is an improvement over the old method of using separate lubricators for each cylinder.

The sight-feed glasses are provided with separate drain-valves, affording the operator means to drain and automatically refill the glass with fresh water of condensation while the engine is running and without emptying contents of the oil reservoir.



A NEW MILLING MACHINE. BUILT BY THE BROWN & SHARP MANUFACTURING COMPANY, PROVIDENCE, R. I.

A NEW MILLING MACHINE.

THE engraving, printed on opposite page, of the new milling machine recently brought out by the Brown & Sharp Manufacturing Company, of Providence, shows the special improvements it possesses. As will be seen, the overhanging arm supports the outer end of the cutter arbor, either on a center or in a bushing, and may be rigidly connected with the knee by an arm-brace, while the saddle rests directly upon the knee, and the heavy platen moves only at right angles with the spindle. It has three T slots, and is surrounded by a channel for oil. The platen is 32 inches long and 7 inches wide. It has an automatic feed of 20 inches, and may be stopped automatically at any point while moving in either direction. It can be lowered 18½ inches from the center of the spindle, and the saddle has a movement of 6¾ inches in line with the spindle. The greatest distance from the center of the platen to the face of the stand or knee slide is 11 inches. There are six changes of feed varying from .008 to .100 inches per revolution of the spindle. The vise swivels and has a graduated base. The jaws are 5⅛ inches wide, 1⅛ inches deep, and will open 2¾ inches.

The overhead works have two friction-pulleys 14 inches diameter for 3½-inch belt, and hangers with adjustable and self-oiling boxes. The countershaft should run about 110 revolutions per minute.

The weight of the machine is about 1700 pounds and it occupies a floor space of 64½ x 44 inches.

Reflections and Observations.

A NEW YORK pump manufacturer not long ago had a peculiar experience with a firm who are very successful manufacturers, but who believe an engineer is unnecessary, so they employ a boy to look after their steam plant and trust to luck. So far luck has been on their side, and the head of the firm is learning considerable about engineering—and is paying for it.

Not long ago a large duplex pump "gave out," and they did not believe it was their fault. In reply to their inquiry about a new pump, the manufacturer of another style requested information about steam-pressure, work required, etc., and a pump that was ample in capacity was shipped arranged to work from an engine, using 100 pounds steam.

The pump arrived in due time, was set up by a steam-fitter, but wouldn't work, and answering a telegram a representative of the pump concern went in hot haste to see what was the matter.

It was examined, the plungers were taken out, piston looked at, and all possible effort made to discover the trouble without avail.

"I can't find out anything the matter with the pump," said the machinist. "Let's see: this pump was ordered for boilers using how much steam?"

"One hundred pounds," replied the man who didn't need an engineer.

"Well, I'd like to look at your boilers. Where are they?"

"What's the boiler got to do with it?"

"Well, I would just like to look at them."

"All right, you can see them, but I didn't send for you to examine my boilers. I've had 'em for twenty years and they are just as good as they were the day I got 'em. Here they are."

It needed but a glance to show what the trouble was. There were two boilers, and the steam-gages registered 50 pounds each.

"I thought you said that you carried 100 pounds steam pressure in these boilers."

"Well, I do, don't I? Can't you count: 50 and 50 is a hundred, aint it?"

++

I READ the other day of a manufacturer who had an engineer who, when his pump would not feed the boiler, went to the proprietor and said they would have to shut down for the rest of the day. The owner didn't want to do that, so he sent for the engineer of another establishment, who, after studying the pump a few moments, picked up a hammer and gave the valve-rod a few sharp raps.

"Put on the steam now, and I guess she'll go," he said, and when the steam was put on she did go.

"Send me your bill," said the mill owner, but when he received it he was rather surprised. The engineer had not spent over half an hour on the pump, but the bill was for $25.00. He protested against the charge as being exorbitant and asked for a new bill.

It came next day and was made out thus:

For fixing pump.....	$0.50 cents.
For knowing how.....	24.50
Total.....	$25.00

He paid the bill.

++

A WELL-KNOWN engineer who has been in the South not long ago found himself in Meridian, Miss., at breakfast time, the train allowing passengers "30 minutes for refreshments."

The fare, however, was not of the quality which epicures get enthusiastic over, so he wandered around the platform and partook of an orange in lieu of corncake and bacon.

Sitting on a truck, basking in the sun, was an old-time negro, who, from his own account, was much better off "befo' de wah."

The engineer in question being of an inquiring turn of mind, asked what sort of a town Meridian was.

"Fine town, sah; dis yer be a fine town. Dey say it be de largest city in de hull country."

"I didn't know that," replied my friend.

"Oh, yes, sah. Whar' yo' bin, sah, yo' neber foun' dat out?"

"I have been a good ways from here."

"Furder den Kentuc?"

"Yes; but tell me, has your town grown much the last few years?"

"Grown? Well, I should say it hab. Grown? Well, you bet!"

"How does it grow?"

"Grow? Well, dey just pars out to der edge an' adds on a little mo'."

"That's so, but do you have any manufacturing industries here?"

"Dat's all wees do. Man'facter eberyt'ing."

"Well, I am going North, and I would like to tell my friends about your place. What do you make here?"

"Why, we make eberyt'ing, as I done tole yer,—candy an' cider an' beer an' eberyt'ing."

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"Do you believe hearing a crowing hen indicates disaster?" asked a lady visitor of one of the firemen at the power-house of the West End Street Railway in Boston.

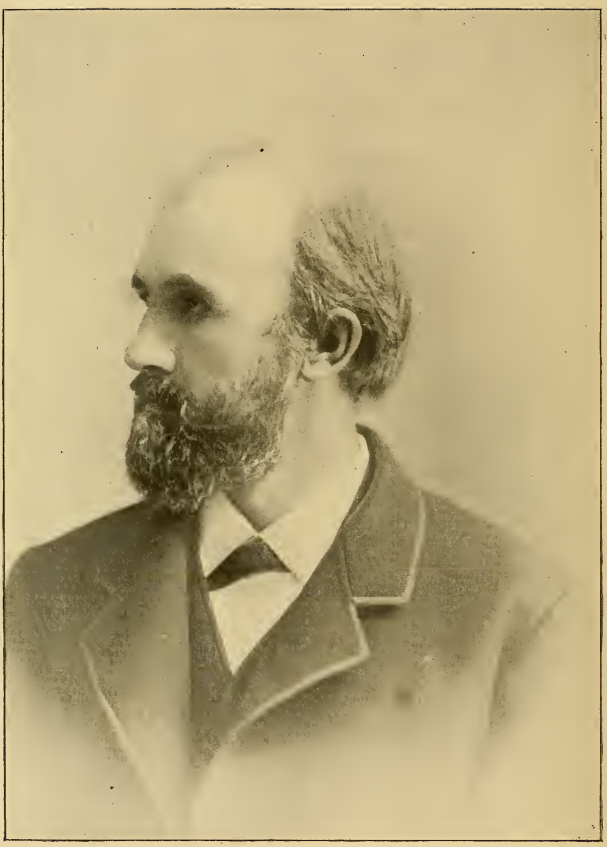
"Never thought anything about it," replied the man.

"Well, wouldn't you be more careful about the steam if you should see the new moon over your left shoulder?"

"No, I don't think I would."

"Well, I think you are brave. Now, the other day I saw a black cat sitting in a window and I knew something terrible was going to happen, and it did. Before night a fourth cousin arrived at my house with four children, two poodles, and nine big trunks, and they nearly eat me out of house and home."

THE OBSERVER.



JOHN E. SWEET.

CASSIER'S MAGAZINE.

VOL. I. APRIL, 1892. No. 6.

ELECTRICAL EQUIPMENT OF MODERN WARSHIPS.—I.

By H. Hutchins, Lieutenant U.S.N.



ELECTRIC search-lights, since the creation of the fast seagoing torpedo-boat, armed with the Whitehead torpedo, have become an absolute necessity for every naval vessel. For a ship to remain in the presence of the enemy on a dark night without search-lights would be but to invite attack. It requires no argument to show that the rapid-fire machine guns supplied to the ship for use against torpedo-boats would without the electric light be most useless when most needed; moreover, it has been shown by actual practice that with a good electric light excellent shooting can be done when firing at a moving target 700 yards distant.

For the detection of torpedo-boats an apparatus giving moderate horizontal divergence is best, as it will illumine an arc of the horizon at once; but when the position of an enemy is once discovered it becomes desirable to concentrate the light on one object, not only to illuminate the target for the gun captains, but also to blind, if possible, those who are manœuvering the enemy's boat. Moreover, it is desirable that as little light as possible shall be lost which might reveal the exact position of the vessel to the enemy.

For war use, therefore, a projector should be capable of utilizing nearly all the light of the arc and of projecting it in a parallel beam to a great distance.

The general form of the projector is the same whatever form of reflector is used.

The type used at present in our navy, as fitted with the ordinary hand-control, is shown in Fig. 1, and is manufactured by the Thompson-Houston Electric Company. The cylindrical body of the projector is mounted on trunnions and the trunnion-supports are fixed on a cap, which is pivoted to the base of the apparatus so that the beam of light may be thrown in any direction desired. Clamps are provided for retaining the projector in any one position. There are a number of holes in the body, the upper ones having a hood for keeping out rain. These holes are for ventilation, as the electric arc is a source of great heat, which without ventilation might disable the apparatus.

As regards the reflector, the parabolic form is theoretically the best means for concentrating the light given by the arc into a beam of parallel rays, but it has many disadvantages.

In the first place, in order that the rays may be reflected into a parallel beam, it is necessary that the luminous body should be a mere point in the focus, and the small electric arc is still sufficiently large to cause dispersion into a cone of light. Again, if the mirrors are large, they are apt to lose their shape

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by their own weight. Besides, a true parabolic mirror is very difficult of construction.

Failing to obtain suitable parabolic reflectors, lenticular systems were next employed; but though the best design and workmanship were given to their construction, they were not satisfactory, as they were very costly, absorbed too much light, and, besides, being open to some of the objections common to parabolic mirrors.

It was these considerations which led Colonel Mangin, while studying the development of optical telegraphy for military purposes, to seek a new form of projector, which he happily found in a spherical glass mirror combining refractor and reflector in a form of comparatively easy construction. The Mangin projector overcomes the difficulties mentioned above in the other forms and has been generally adopted by all modern navies. The mirror consists of a concavo-convex lens, the convex surface having the greater radius. The concave side is turned to the light and the convex surface is silvered. It is therefore a reflector, but the radii of curvature of the faces are so calculated that the two refractions at the concave surface almost completely destroy all aberration, and this gain more than counterbalances the loss by reflection. With a projector of 60 cm. diameter the beam has a divergence of only 2°, being 35 meters wide at a distance of 1000 meters, the mouth of the projector being closed by a simple plain lens. The projector is furnished with lamp and connections complete and of the following sizes:

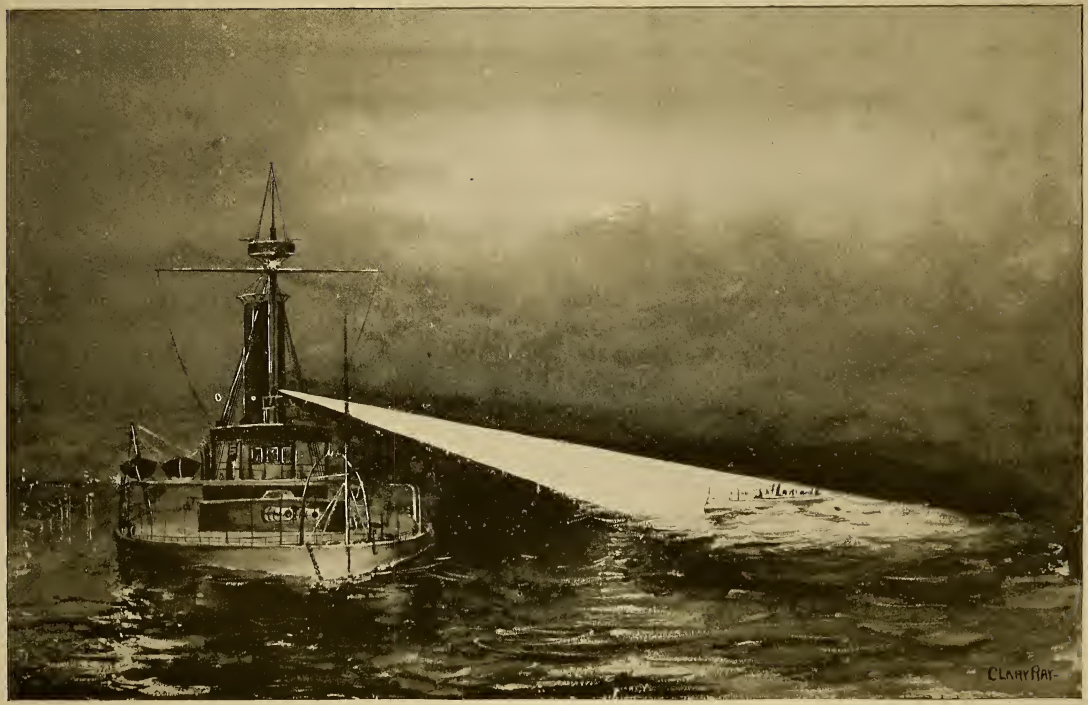
30 cm.	diam.,	focal distance	16 cm.,	current	20	ampéres.
40 "	"	"	24 "	"	40–50	"
60 "	"	"	33.2 "	"	50–80	"
75 "	"	"	54 "	"	80–120	"
90 "	"	"	76 "	"	150 or more	

The inclined position of the carbons is due to the fact that a great part of the light is furnished by the crater formed in the upper positive carbon, and therefore it is advantageous to have this crater exposed toward the mirror as represented. The best disposition, determined by experiment, is that by which the crater is made to form an angle of about 30° with the axis of the carbon by feeding the upper carbon with its axis slightly out of line with the lower. The inclination of the lamp in the projector is about 30°. A small fixed reflector of such dimensions as to turn back all rays which would otherwise escape from the arc in divergent directions is secured in position on the rod joining the carbon-holders. Hence it is evident that the greater portion by far of the light radiated is thrown on the Mangin mirror. For very short distances a brighter illumination could be obtained by turning the lamp around, but it is obvious that the actual arrangement is better for the purpose intended, for with the lamp turned around the decrease in illumination would be nearly as the square of the distance, while with this arrangement, though the illumination near the instrument is less, owing to losses by refraction, reflection, etc., the decrease is only as the first power of the distance.

A 45-volt arc with a current of 50 ampères produces a light at the projector of about 12,000 candles. The 60 cm. projector, with the lamp taking 75 ampères and the beam concentrated, should give a range of 2 to 3 miles; that is, should make light objects plainly visible at that distance on dark nights (no fog or mist).

The typical lamp for naval projectors is a combination one; that is, either automatic or hand-control can be had as desired. If the projector itself is to be trained by hand, it is very little more trouble to use the hand-lamp. In any case, to make the lamp reliable, one condition is that, whatever be the nature of the feeding mechanism, it must be independent of gravity in order that it may work equally well in a seaway. Simplicity, close regulation, and rapid focusing are also necessary requirements of the search-light as distinguished from commercial lamps. In some marine automatic lamps the feeding is accomplished as follows: The rise of potential as the arc becomes longer sends a current into the armature of an electric motor, which rotates, and in so doing brings together the carbons through the intervention of mechanical gearing.

The lamps supplied the French navy, and manufactured by Sautter, Hadé et Cie, of Paris,—and who, by the way, are the pioneers in marine search-light apparatus,—may be described as follows:

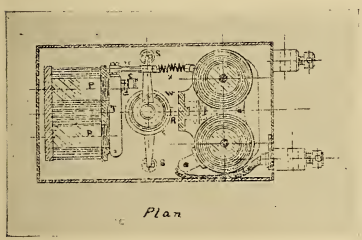


TORPEDO-BOAT BEING DISCOVERED BY USE OF SEARCH-LIGHT ON U. S. S. MIANTONOMAH.

The automatic lamp for projectors is composed essentially of two screws *A* and *B*, one with right-hand thread, the other with left, and the amount of pitch being proportional to the consumption of the positive and negative carbons. Upon each is mounted a nut *E*, *N*, carrying respectively the positive and negative carbon-holders. The two screws *A* and *B* are fitted to the special coupling *G* in such a manner that on turning it to the right the carbons will approach each other and if turned to the left they will be separated. This movement can also be obtained by moving by hand the wheel *H*.

On the prolongation of the screw *A* is keyed a bronze box *W*, in the interior of which is placed a beveled split ring. A lever *Z*, carrying two pins, permits :

(1) Of connecting the two edges of the split in the ring *V*.

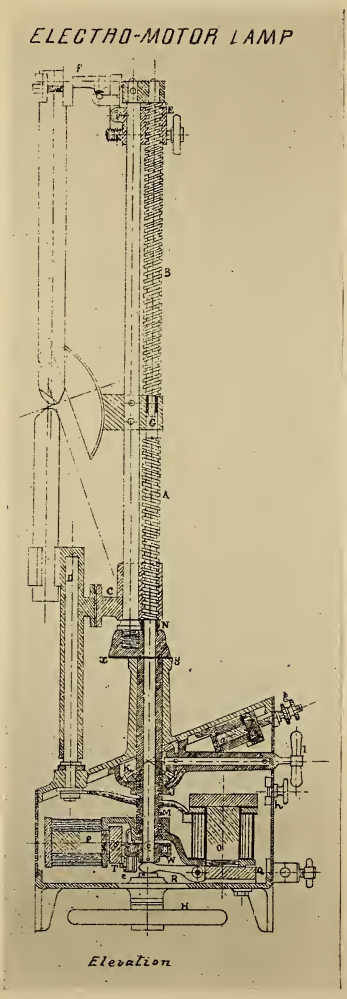


Plan

(2) Of separating them.

In the first case the exterior diameter of the ring *V* is diminished and the ring is free to turn in the box *W*.

In the second case the exterior diameter of the ring *V* is increased, and its exterior surface bears against the interior of the box *W*, which is obliged to follow the movement of the lever of the ring *V*. The lever *Z* is joined by a small rod *U* to the armature *T* of a fine-wire electro-magnet *P*, connected in multiple with the two terminals of the lamp. A relay *a* sends at the right time a current into the electro-magnet *P* by way of the contacts *b* and *c*. A spring *X*, whose tension acts in a direction against the electro-magnet, brings the armature to the initial position. The electro-magnet *a* of the relay is of equally fine wire and in multiple with the arc. Its circuit is closed by a contact *d*, *e*, placed on the armature of the electro-motor *P* only when it is at its initial position. The circuit of the relay is broken when it



leaves that position. A spring *f* placed on the armature of the relay acts in an opposite way to the electro-magnet ; it can be held in more or less tension by

means of a small screw and thumb-nut *g* placed on the outside of the lamp. A commutator *Y* is connected with the

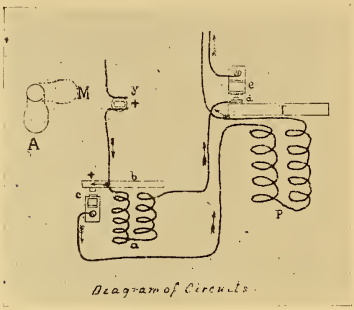
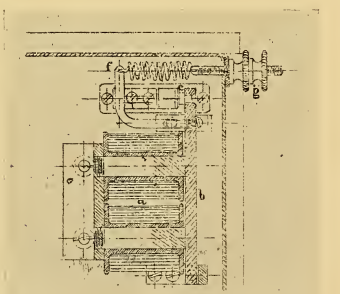


Diagram of Circuits.

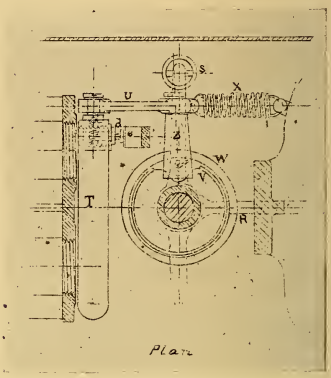
circuits of the two fine-wire electro-magnets and permits the breaking of the circuit when it is desired to work the lamp by hand. In this connection it will be noted that it is always necessary in this case to break the current in the electro-magnets by placing the handle of the commutator on the letter *M* before moving the wheel *H*. The arc is struck automatically by an electro-magnet *O*, in-


Plan of Relay.

terposed in circuit, which at the instant of the current passing attracts its armature and gives, by means of the lever *R*, a downward movement of the whole lower carbon-holder system. The exact placing in the focus in the vertical direction is made as in the ordinary hand-lamp by a wheel *i*, which works, by means of a pinion *k*, both the carbon-holders. A white line engraved on the sleeve *M* indicates that it is in the mean position when it is in the plane *x*, *y* of the sleeve of the outer surface-plate of the lamp.

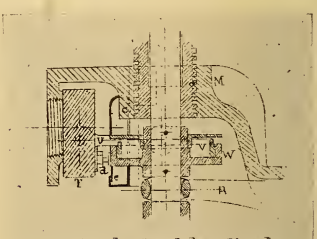
The working of the lamp is as follows.

Turn the commutator on the mark *A*. The current passes in the fine-wire elec-



Plan.

tro-magnets. The electro-magnet *a* of the relay attracts its armature and makes contact between the two points *b*, *c*, closing in consequence the circuit of the electro-motor *P*, which in its turn attracts its armature, drawing in its movement the lever *Z*, and in consequence the ring *V* and its box *W*, keyed on the screw of the two carbon-holders. The latter, turning in the interior of nuts *E* and *N*, cause the carbon-holders to ad-



Automatic Regulator. Elevation.

vance toward each other by a small amount. At the moment the armature *T* of the electro-motor is attracted it



SEARCH-LIGHT USED AT A WRECK.

breaks contact at *d* and *e* and breaks the circuit of the relay *a*, of which the armature, yielding then to the spring *f*, is returned to its initial position, breaking in its turn in this movement the circuit of the electro-motor *P*, whose armature, under the action of the spring *X*, is returned then to its initial position, closing again in this movement the circuit of the relay *a*, which attracts its armature, sends a current for the second time into the electro-motor *P*. This vibrating movement continues until the carbons are brought together. At this moment the striking electro-magnet functions and the arc is "struck." The regulating of the lamp consists in giving to the spring *f* of the relay a tension such that the attractive force of the electro-magnet *a* will overcome the spring *f*, for a potential at the terminals of the lamp of 45 to 50 volts, suitable to maintain an arc in its best condition.

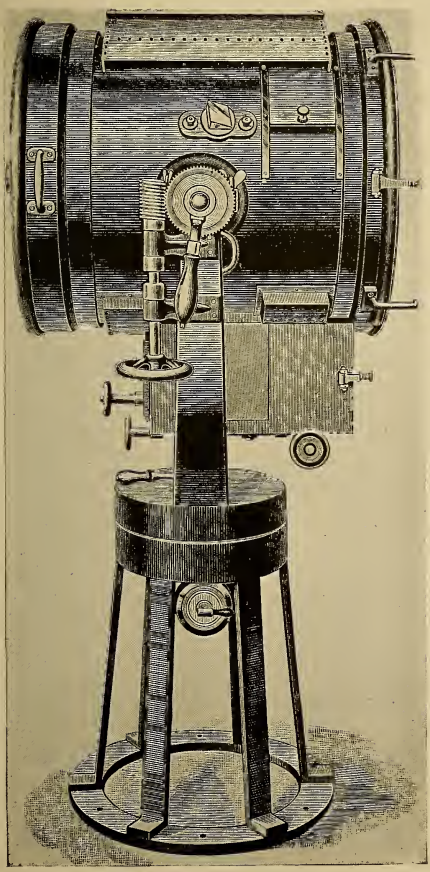


FIG. I.

By turning the button in the direction of the arrow *R* we distend the spring and augment the frequency of movement of approach. We do the contrary by turning it in the direction of the arrow *E*. To work the lamp by hand, turn, as we have said, the commutator on the letter *M*, then work the wheel *H* by hand.

One of the latest improvements in search-lights abroad is that which allows them to be manipulated from a distance. Not only is the lamp automatic, but motors are attached for training, both horizontally and in elevation. In this way the projector is electrically controlled, one man only being required, who would be stationed in the conning tower or other protected position. The *New York*, the large armored cruiser constructed at Cramps', is equipped with six of these electrically-controlled projectors of 75 cm. diameter. The movement of training can be either rapid and continuous, in order that the object of search may be brought under the beam, or it may be by small, almost imperceptible changes, either horizontally or vertically, in order that the object under examination may be exposed in detail to the beam. Thus the operator controlling the light can apply the fastest or slowest movements or can stop the mechanism instantly. Again, the control at a distance can be changed for the ordinary hand-control.

The mechanism of the projector is placed in the base on which it is mounted. The principal details are : A double elec-

tric motor with two armatures; suitable gearing for transmitting the movement to the turn-table of the projector for producing the horizontal and angular displacement of the beam; an automatic interrupter limiting the angular movement in both directions.

The apparatus is controlled by two spring handles, one for the horizontal and the other for the angular (vertical) movements; these handles are placed at right angles to one another and their position is such that the movements made by the hand of the operator correspond to what it is desired to impart to the projector. Pushing the handle to the right causes the beam to be deflected to the right; pushed to the left, the beam turns to the left. The mechanism is so arranged that as soon as the operator relieves either of the handles it returns to the zero point and all further motion is immediately arrested. It is easy at will to obtain a definite range of speed or a series of concerted movements. A cable connects the controlling mechanism to the projector; it is made up of the requisite number of conductors, the ends of which are attached to the numbered terminals outside the case of the apparatus.

Moreover, the valuable quality is given to the beam of concentration or dispersion at will, so that a much more perfect surveillance of the obscure space around the vessel can be maintained. The optical system as devised by Sautter, Hadé et Cie consists of two dispersion openings provided with plano-cylindric lenses, alternately concave and convex. One of these openings can be moved forward longitudinally by means of an endless screw controlled by a hand-wheel placed behind the drum. The other opening is fixed. In turning the hand-wheels in one direction or the other the moving opening is passed in front of fixed one; the lenses are calculated in such a manner that their partial overlapping widens or concentrates the beam. In one of the extreme positions the concentration is at a maximum and the angle of the beam does not exceed 2°; the ray is there identical with that given by a projector enclosed by a plane glass, and the zone, illuminated at a range of 1000 meters, gives a width of 35 meters. In the other extreme position the dispersion amounts to 20°, and the path, illuminated at a distance of 1000 meters, would have a width of 350 meters; the intermediate rotation of the hand-wheels produces all the intermediate positions.

While the Mangin mirror still maintains its superiority for naval projectors, the large German firm of Messrs. Schuckert & Co. have developed and introduced quite a successful projector fitted with a glass parabolic mirror, the general build and arrangement of the projector being otherwise quite similar to the Mangin. One of these glass parabolic mirrors (silvered at the back) of 43 inches diameter has a focus of 20 inches. The carbons are generally placed horizontal.

A competitive trial was had recently of a 60-carbon Mangin projector electrically controlled and a 60-carbon Schuckert projector (parabolic mirror) controlled by hand, the lamps of both projectors being of the automatic type. The current strength was 85 ampères in the Mangin and 75 in the Schuckert. The result of the tests may be best stated that with the Mangin the details of construction of a light-colored house could be made out with the aid of glasses at a distance of 7200 meters. The greatest distance at which it was possible to discern the same object with the German projector was 4800 meters.

Finally, while the search-light is considered in all navies to be a necessary part of the equipment of a modern war vessel, whether it be a large battleship or a torpedo-boat, it must be remembered that great caution must be exercised in its use, in order that it may not betray the presence of its own vessels as often as it reveals the presence of the enemy. We are particularly in ignorance of the real value of the search-lights in action when employed at the same time against each other. The number, size, and best disposition of the projectors fitted to any particular ship, as well as the relative value of electrical and hand control, are all questions which remain to be decided by a naval campaign.

ENGINE TESTING.

By M. C. Ihlseng, C.E., E.M., Ph.D.

THE comparative frequency of very bad cards taken from engines being indicated, similar to that represented on page 252 of the January number of this magazine, must forcibly impress steam-users with the necessity for an investigation of the behavior of their machines. Such an ocular demonstration of the waste of fuel should convince mill men that the use of engines under such conditions of derangement simply invites bankruptcy. Upon one occasion, when the writer was proceeding to test an engine, he was met by the engineer with the query, "What is the use of testing my engine? She works all right. There is no leak, she don't knock, and I keep her well iled." Were these the only tests of the satisfactory working of a machine, the life of a mechanical engineer would be a happy one. But, alas! the avenues of loss of power are too numerous to be revealed by any one irregularity, such as mentioned by the engineer. The indicator and dynamometer disclose diverse unsuspected and easily remedied wastes that decrease the longevity of the machine and needlessly increase the fuel account.

It is true that the knocking of an engine is an evidence of bad behavior, but there are many other more insidious sources of waste. Whenever an element of a machine is loose, or out of line, a jarring ensues with every change in the direction or the velocity of motion. So that loose piston rings, steam condensation in the cylinder, badly-worn pitman bearings, or poorly aligned shafts, or cross-heads, are the primary cause of a chattering that injures the quality of the steel, invites breakage, and loses power. Inequalities in the cylinder surface are also very apt to cause knocking that no amount of oiling may remedy and only indicator-cards will reveal. If the bearings are cushioned they may be run slacker, but while they conduce to less friction, they are not, theoretically, commendable.

There may be no leak manifest at the stuffing-box, which, however, may be so tight that a steam leakage might be cheaper. The pipes and valves may not leak, but their size may be so small or their bends so short as to resist the supply of steam, and the higher the piston speed the more serious becomes this restriction. Unprotected induction pipes still further reduce the pressure and thereby the efficiency. Again, the exhaust may be so small as to cause a back-pressure even greater than the total engine friction. And, finally, the slip of valves, an imperfect cut-off, or a piston poorly packed may produce such excessive fluctuations of power as to utterly incapacitate the engine for any work.

These and other defects may be disclosed by testing and a material economy be effected by their correction. William Kent, figuratively speaking, in his article in a recent issue of this magazine, on "PreventableWastes of Heat," has ably specified the remedies for the general debility of boilers, and it will be our endeavor here to suggest the mode of revealing the engine wastes and irregularities by the use of diagnostic instruments.

The method of examining into the calorific efficiency of a boiler consists in weighing the relative amounts of water evaporated in the boiler and of fuel consumed in the furnace during a given period of time. The testing begins at a time when everything is at a normal working temperature. The fires are drawn and a new fire built up and maintained by weighed amounts of combustibles. The temperature and the height of the water in the boiler at the beginning are noted, as also the weight and temperature of the water delivered during the test, and that remaining at the end of the period. At intervals of five or ten minutes the boiler-pressure is noted. All possible precautions are taken to procure dry steam. Leaks are carefully stopped and the

safety-valve is set considerably higher than the working-pressure. The amount of steam thus produced, reduced to the consumption of one pound of the combustible, gives the thermal value of the fuel, furnace, and boiler combination. The individual influence of each element of the combination is not easily determined. Fuels have different personal equations of behavior in the different grates, while the relationship of the latter to the boiler is empirically established.

For the purpose of ascertaining the effective dynamic value of the steam, and thereby of the fuel, in the motor, the device known as the indicator is used for recording the relative pressures of the steam during the various phases of the stroke. There are many varieties of the instrument, as may be seen by reference to the advertising pages of this magazine, and no description is necessary beyond defining it as an auxiliary cylinder, or drum, in which a piston is held down by a spring against the pressure of steam drawn from the engine-cylinder. Connected with the indicator, piston, or its spring is a pencil, which rises and falls with the fluctuations of pressure and registers the same upon a sheet of paper wrapped around the drum which is caused to revolve by a suitable appliance. The position of the pencil indicates the pressure being exerted at the moment upon the engine piston, while the diagram *in toto* reveals all that has transpired during the stroke. The instrument is cheap, simple, and effective, giving information which is direct.

The indicator is attached to the top or sides—never at the bottom—of the engine-cylinder by a ½-inch gas-pipe entering close to each end. The springs used are supplied of various numbers, graded in such manner that the number signifies the pressure in pounds per square inch which will produce a pencil movement of one inch vertically. Though the rule is to use a spring, whose number is one-half that of the boiler-pressure, certain emergencies may necessitate a spring of different number, in which case it is advisable to be provided with several.

The paper to be wrapped around the drum is what surveyors call cross-section paper, which being divided into squares simplifies calculation. The diagram should be drawn as long as possible in order to eliminate errors of estimation, the average being about 4 inches. High-speed engines, owing to the inaccuracies arising with their rapid reversal of motion, are more accurately measured from shorter cards, of, say, 2½ or 3 inches.

The drum is revolved by the unwinding of a braided cord which receives its motion from the cross-head through a combination of reducing levers adjusted to produce the length of diagram desired, Fig. 13, where O, V is the length of stroke and a, b is the length of the diagram desired, being a ratio to the stroke as $O, C : a, C$.

When the parts are properly attached the records are taken, but not until both engine and indicator have been run for several minutes. The pencil will then be found to have traced a more or less simple curve upon the paper, which may easily be interpreted by the light of our knowledge of the behavior of gases under changes of pressure.

Let Fig. 1 represent a sheet of paper about the drum on which are drawn lines at right angles to each other. Suppose the drum to be stationary, while the steam-pressure rises to a point B.



FIG. 1.

If now the drum revolves while the steam-pressure remains constant, the pencil would describe the line B, S. Let the steam be cut off instantaneously and the pencil would drop along the line S, A until the pressure of the atmosphere was reached. On reversing the direction of the drum the pencil would follow the line A, A to the point of be-

ginning. The diagram below, theoretically, could be taken from an ideal slide-valve engine without clearance or leak and whose induction and exhaust-valves are instantaneous in their action. The water-cylinder of a steam pump should give the same card. A cut-off engine would give a similar diagram for that portion of its stroke which is under full pressure, but from the point of cut-off the pencil will register a constantly decreasing pressure, as shown in Fig. 2, provided the valves feed instantly and perfectly. These lines express theoretical conditions and the nearer they are approached by an

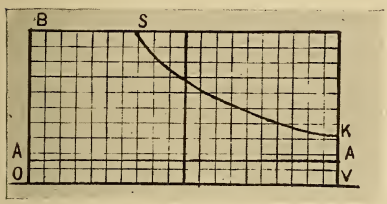


FIG. 2.

engine record the more perfect it is. Conversely, the more they depart from the theoretical curves the greater is the waste. As a matter of fact the diagrams from the two forms of engines mentioned more nearly approach those depicted in Figs. 3 and 4 respectively.

As in the former diagrams, the horizontal lines through *P* and *O* represent respectively the boiler and atmospheric pressures. It is important that these lines, as well as the vacuum line *A*, *A*, should be established carefully. The vertical distances between them measure the gage and absolutes pressures at any moment.

B is the line of boiler-pressure; *P*, point of steam admission; *D*, *S*, line of steam-pressure; *S*, point of cut-off; *S*, *K*, line of steam expansion; *K*, *K*, line of ideal expansion; *K*, point of exhaust-opening; *K*, *L*, line of exhaust; *L*, *M*, line of back-pressure; *M*, point of exhaust-closure; *M*, *P*, line of steam compression in the clearance.

It will be noted that the steam expansion line is concave outward and all the other curves are convex outward. This is always true and if ever the curves are encountered reversed or straight there

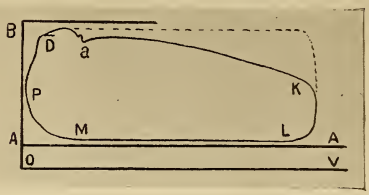


FIG. 3.

is something abnormal surely. Leaks are the simplest explanation of the vagarious lines, the presence of which reveals derangement in the mechanism or defects in its workings.

If the induction-pipes from the boiler to the cylinder are ample in size, straight, short, and well-lagged, there will be very little resistence to the flow of the steam and very little condensation due to it. This state of affairs will be shown by the nearness of the steam line to the boiler line while a low steam line is due to a restriction of the steam supply. Contracted steam ports may also contribute to a low initial steam-pressure, but even if they prove to be the sole cause of a low steam line, it may not be always advisable to enlarge them, for often the

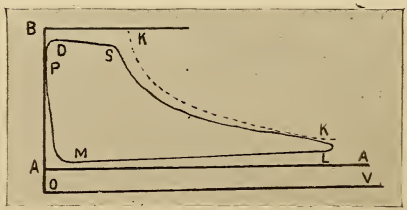


FIG. 4.

resulting gain may not compensate for the heavy losses otherwise due to large ports.

If the steam line begins to fall off, there is not enough steam admitted, or perhaps a condensation has taken place. Sometimes the line drops off suddenly enough to bring about an accidental expansion. Wire-drawing may explain

this initial expansion. In Fig. 4 may be seen such a line at *D, S*. The falling off of this steam line results in a low final pressure and thereby a reduced mean effective pressure. Still this is not so serious a loss in the fixed cut-off engines as it is in the automatic. Sometimes the steam line will have some singular jogs, like that shown in Figs. 3 and 5. This can only be accounted for by the cut-off valves during the act of closing, first dropping and then rising, allowing the steam to enter the too large induction ports. A guard would remedy this chattering. When the cut-off valve is behind time in automatic engines, these serrations are also seen. The poppet-valves of an air compressor often give similar undulations. Indeed, the very erratic lines occasionally found on the cards are usually explained by a

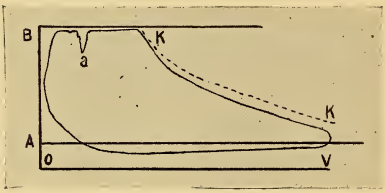


FIG. 5.

bad setting of the valves. However conscientiously the valves may be set by the manufacturers before shipment, transportation or subsequent running may derange them seriously. The graphic evidence of the cards taken from one end alone is not conclusive as to leakage, but those taken from the other end of the cylinder may confirm the supposition and both together will be an infallible guide.

Some of the sinuous lines, or serrations, in the curve may also be due to the bad behavior of the indicator mechanism, particularly when attached to high-speed high-pressure engines. Oscillations of the pencil and piston, while being accommodating to the rapid excessive changes, result in such a card as Fig. 6 at *B*, and at *b*, Fig. 7. Sometimes chattering results from condensation and subsequent evaporation. The irregularities from the latter cause are larger than those from the case first mentioned.

The quickness of the cut-off is judged by the sharpness of the curve at *S*. The behavior of the exhaust-valve may be similarly gaged. A leaky valve rounds

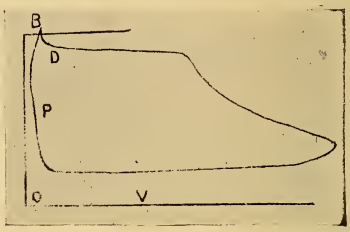


FIG. 6.

off the curve. The positions of the cut-off and exhaust-valves, opening and closing, are determined by the points of flexure of the curve. It is not unusual that the cards will show the point of cut-off to be much later than the valves are believed to have been set at. This is particularly true of high-speed engines. A rounded curve also may reveal contracted port areas and lack of lead.

After the cut-off has taken place the expansion of the steam results in a pressure, decreasing with the increasing volume to be occupied,—the increasing piston displacement. If now on the

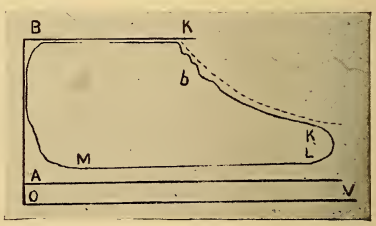


FIG. 7.

diagram, besides the datum lines mentioned, there is drawn from the point of cut-off the logarithmic curve of expansion, as *S, K* in Fig. 2, many additional facts in connection with the behavior of the steam may be learned. If the point of cut-off is sharply defined, the expan-

sion curve may be drawn from it. Otherwise it is traced backward from a point as near as possible to the point of opening of the exhaust-valve. This point, *K*, may be recognized as being the point of inflexion of the curve from concave upward to convex outward.

The expanding steam should follow the normal curve, *S*, *K*, but this very rarely occurs. Usually the pressure falls below it and tells of steam that is wet, or of a cylinder cold from radiation, while a very great fall suggests a loose piston packing or a rate of expansion too high for the thermal changes. Sometimes near the end a rise in the actual expansion curve will be noted, as in Fig. 7. This is an abnormal phenomenon and may indicate a re-evaporation of the condensed steam, or else a leak in the ports.

The remedies in such cases would be found in jacketing the cylinder, or in producing a better quality of steam. While either in itself is an improvement, dry steam is absolutely essential to the successful operation of the jacket. Wet steam is sluggish and has less elastic force than the dry gas. Its condensation always results in "knocking" by accumulating in the clearance-space. In engines of high speed or small clearance this may prove very serious. Wet steam is the result of forcing the boilers too hard. While a larger boiler capacity may materially remedy the complaint, more or less moisture is unavoidable. Mechanical devices called "eliminators" are doing excellent service in automatically separating the water from the dry steam.

Jacketing the cylinder is an undoubted economy. Professor R. H. Thurston says, "An ideal non-conducting cylinder gives higher efficiency than an ideal jacketed engine," but "the real engine with its combined jacket and cylinder wastes reduced by the jacket, as the latter are, to a minimum, is more efficient than the same real engine would be without a jacket." "In ideal cases jacketing results in loss; in actual cases it commonly produces a gain."

If a rise in the curve of expansion occurs in a jacketed cylinder, it is likely due to a superheating of the steam at the end of the stroke, because the cylinder is hotter than the final steam. Generally the opening of the exhaust-valve in condensing engines produces a rise of pressure instead of a fall. Then the exhaust line, *K*, *L*, rises frequently to form a loop, as is shown in Fig. 8. If the loop is very large the engine is much too large for its work.

To facilitate the escape of steam, the opening of the exhaust takes place at the point *K*, before the piston begins its return. The curve will then drop off rapidly around to the point *L*. A very much rounded curve indicates a contraction, or bends, in the exhaust passages to offer resistance to the release, as shown by the excessive back-pressure line, *L*, *M*, Fig. 7, during the recording of which the piston is returning and expelling steam. A sharp curve indicates a deficiency of early release. The release should be such that one-half the fall in pressure should occur before the piston has reached the end of its stroke, the other half on the return, as in Fig. 7. It is true that a rerelease loses work of the forward stroke, but that is fully compensated for by the gain during the return. *M* is the point of closure.

The line *L*, *M*, therefore, represents the pressure required to expel the steam from the cylinder plus that required to overcome friction. As a good non-condensing engine has rarely over 3 or 4 pounds of friction, the counter-pressure should not exceed this gage reading. Engines supplied with a cold large condenser generally show 6 or 7 pounds above a vacuum; but the writer believes that their valves are usually built too small. That the back-pressure is greater than it should be may also be due to the air carried over with the steam. All of the above-mentioned quantities represent a loss due to exhaust resistances. The excess of back-pressure is less the greater the ratio of expansion. The impairment of the condenser vacuum, owing to the presence of air, is tolerated because the air assists the boiler evaporation. The pumping of the air only consumes about one pound of pressure.

As the point of closure affects the amount of steam remaining in the cylinder, so it must needs proportionately

influence the back-pressure. An early closure conduces to a high back-pressure, and this in turn reduces the effective pressure. Larger ports or a later closure are the only cures. The latter, however, results in a very slight compression with the great liability to "pounding." A proper adjustment of the two opposing desiderata—a low back-pressure and a high compression—is only attained by careful trial. Most exhaust-ports are closed too late to secure the most beneficial results of compression.

Nearing the end of its stroke, the piston compresses the steam remaining after the closure, and the curve rises from *M* to *P* on the "compression line." Though it produces a high back-pressure for a short time and is wasteful of power, it offers several advantages: the clearance-space is filled with waste steam instead of live steam, the liability to pounding is reduced, and a smoother running, more equable reversal of motion, and higher speed are attained because of the moderate uniformity of pressure. An excessive compression is to be avoided, but its amount and influence is only to be ascertained by inspection of the diagram and by trial. The present practice is to so adjust the valves as to give a comparison capable of overcoming the final pressure plus the momentum of the reciprocating parts. This is somewhat over two-thirds of the boiler-pressure. Reducing the inside

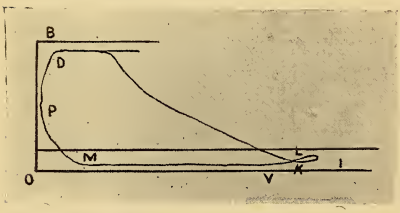


FIG. 8.

lap reduces the amount of the compression, a suitable adjustment of which will counterpoise the reciprocating masses. There is such a thing as carrying the compression to too great an extent, for then the valves tend to wear "lopsided." Trial only determines the best rate of compression for a given clearance. Of course a diagram having square corner, as at *o*, Fig. 2, shows no compression.

In time, just before the piston has reached the end of its return stroke, induction begins (it is called preadmission). This is shown by the rapid rising of the curve, as at *P*, *D*. In Fig. 2 the induction is practically instantaneous. A diagram like Figs. 4 and 7 shows that the steam ports do not open until the piston has started on its forward stroke, while if they open too soon the curve is like the lines in Figs. 6 and 9, where the lead is excessive and the eccentric should be set back a little. When the admission curve is rounded, the induction is late, and the valves require more lead. The amount of the alteration should depend upon the smoothness of running. Condensing engines may, however, have more lead than non-condensers. The point of admission is regulated by the lead and the compression, and begins when the clearance is filled with steam at nearly three-fourths of the boiler-pressure.

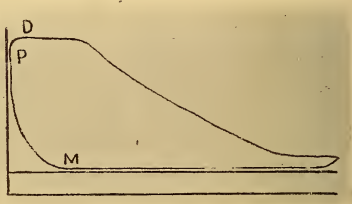


FIG. 9.

It is now evident that as the height at which the pencil stands corresponds to the cylinder-pressures, and any point along the length of the diagram to the piston position, the indicator is really a stethoscope to the interior working of an engine. Not only may it indicate irregularities in the valves, etc., but the steam consumed and the work done may also become known. Many of the diagrams have such erratic curves as to suggest remarkable causes of crookedness. Some that the writer has seen were almost impossible of interpretation. Its registry is not absolute and

infallible, for some of the errancy is traceable to the mechanism. The error of the machine being about 5 per cent., its use is prohibited for the testing of friction or of powers that are less than a twentieth of the total. The waves at *b*, Fig. 7, and the pinnacle at *B*, Fig. 6, suggest some of the peculiar forms due to the inertia of the instrument. Even closed loops at *B* are not uncommon with high-speed engines.

The effective power exerted by the steam is calculated from the diagrammatic area, and is called the indicated horse-power. The area is divided into ten or more equal spaces by a series of ordinates parallel to the line of pressure, and included, vertically, between the curves, and laterally between the clearance-spaces. The use of the cross-section paper, shown in Figs. 1 and 2, facilitates this calculation. The mean effective pressure during the stroke is ascertained, then, by adding to the half sum of the end ordinates the sum of all the intermediate ones and dividing by the number of spaces taken. The mean effective pressure multiplied by the area of the piston and the piston speed equals the number of dynamic units of work. All that part of the curve below the atmospheric line is accredited to the condenser as work saved, though the fact that the compression line is not the same for a condenser as a non-condenser makes this allowance slightly incorrect.

To ascertain the quantity of steam per minute corresponding to any portion of the stroke, we have but to multiply the number of strokes per minute by the weight of a cubic foot of steam corresponding to the pressure at the point selected, and that by the area of the cylinder, times the stroke up to that point plus clearance. There is, however, a difference between the actual consumption of steam and that calculated from the diagram, in every case, except with dry steam in a jacketed cylinder. In other cases the diagram shows the calculated consumption to be less than the actual, and with wet steam the difference is very great. The diagrammatic consumption of steam of a poorly jacketed cylinder at the release is usually greater than the initial quantity at the cut-off.

The simplest mode of obtaining the amount of clearance, which is about 10 per cent. of the piston displacement, is to measure the volume of water poured in to fill the space between the cylinder-head and the piston when the crank is at a dead center.

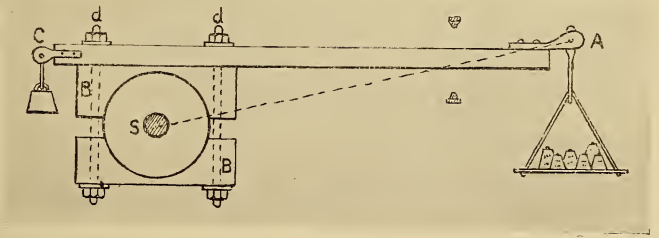


FIG. 11.

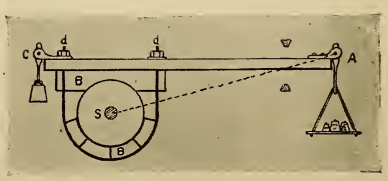


FIG. 10.

Having now ascertained the fuel consumption, the steam production, and the indicated work of the engine, there still remains for a complete test to determine the amount of motive power actually available. This is less than the

indicated horse-power by the amount of the engine friction. The work actually being performed is measured by a dynamometer attached to the engine-shaft or drive-pulley.

cator and dynamometer tests are made with the belt thrown off, with the line shaft on, and then with the machines successively attached.

For small dynamos another form of

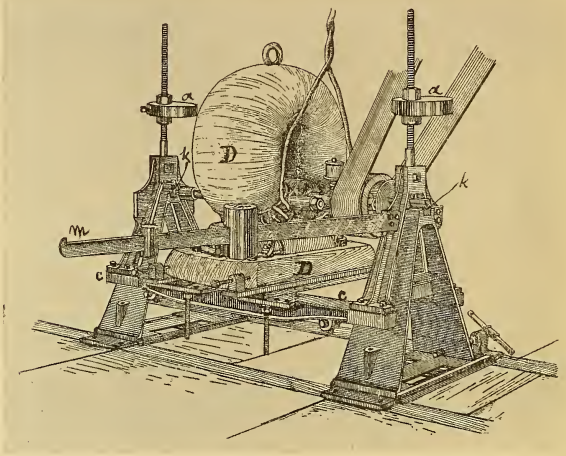


FIG. 12.

Dynamometers are of different patterns, but in Figs. 10, 11, and 12 are illustrated the three most commonly used. *S* is a shaft of the engine or machine to be tested. A pair of wooden brake-blocks, *B*, *B*, are forced against it or a pulley keyed on it by the tighteners *d*, *d* on a heavy lever, *A*, *C*, from the ends of which scale-pans are suspended, the one at *C* being the counterpoise to the weight of the lever. After the engine and shaft have acquired the ordinary speed of working, the blocks, *B*, *B*, are firmly clamped. As the end of the lever, *A*, rises, weights are added to balance the friction. The number of revolutions are counted. The continued product of the revolutions per minute by the weight in pounds, and the circumference of the circle whose radius is *S*, *A*, is equal to the units of work being performed.

The power necessary to run one machine or a line of them is ascertained by this same appliance. Separate indi-

dynamometer is used at the School of Mines. The dynamo, *D*, is placed on

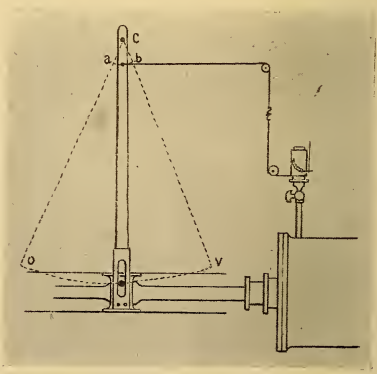


FIG. 13.

a cradle, *c*, *c*, which rests on the knife-edges, *k*, *k*, of the supports. The cradle

with its machine is balanced by the counterpoises at *a*. The dynamo is driven by its belt, the cradle swings out of plumb, the lever *m* moves over an arc, and the weight required to restore equilibrium is noted.

For determining the influence of a very tight piston-rod sleeve, of unbalanced valve-gearing, or of any other cause contributing to increase friction, the indicator and dynamometer are equally useful. The efficiency of the engine working under a light or heavy load, the effect of adding condensers, or the relative value of fly-wheels may be ascertained by proper interpretation of the diagrams. While testing engines with a variable load the various changes of speed must be carefully noted, as otherwise the fluctuations of the governor will seriously affect the test. So also in the case of combination of a very sensitive governor with a light fly-wheel.

Under-loaded engines should be run slow in proportion as their mean effective pressure is high. These cases are the most common as well as the most aggravating complaints that the engine doctor has to deal with. A boiler of excessive capacity may be desirable, but an engine too large for its work is not economical unless properly treated. Decreasing the speed of the under-loaded engine, by diminishing the work of friction, gives a greater fuel economy than would be attained by decreasing the pressure.

Overloaded engines are very much assisted by increasing the speed, unless the ports and valves should happen to be too small to allow of it. In this event a high initial pressure or the addition of a condenser is the only remedy.

HOW TO FIRE A BOILER.*

By R. Hammond.



THE waste of fuel due to improper firing is often of more consequence than any other loss which is produced in the operation of a steam plant, it has been said, but in a great many cases the waste of fuel cannot be entirely charged to improper firing, as there are other causes by which a waste of the evaporating power of the fuel is produced. The principal of these are the following :

The improper construction of the boiler in relation to grate surface, tube area, heating surface, and combustion chambers. Unless these proportions are properly worked out (it matters little whether the firing be done by mechanical means or by the more intelligent fireman), waste of fuel must necessarily follow. A great many contrivances have been placed on the market, such as mechanical stokers and other means by which coal and air can be supplied to the furnaces of steam boilers for the purpose of obtaining good combustion without producing a waste of heat by allowing too much air to pass above the grates or an insufficient supply below the grates. By this statement I do not mean that any particular method of firing will produce any more heat from a pound of coal than Nature put into it. Just as good results can be obtained from hand-firing as have been obtained by the best mechanical means.

It is often the case that firemen are paid insufficient wages for the work they are expected to do. We should be as particular to have good firemen in charge of our boilers as we are in having good engineers in charge of our engines. A good fireman should be just as capable of manipulating the furnaces of his boiler so that his steam recorder and

* Paper read at the Buffalo Convention of the National Electric Light Association.

his coal and water records will show just as good cards as the engineer can show in the manipulation of the steam he uses in his engine. If we paid the same attention to all the details of the construction and setting of our boilers and their economical use of fuel as we do to our engines, our steam plants would be far more economical. Everything is "*shined up*" about the engine; engineers go into all the details of its construction and management and the greatest care is taken in the figuring out of its proportions so that it will have the very highest possible initial steam-pressure and temperature and the very lowest possible terminal temperature and pressure; all endeavoring to get the greatest horse-power from the pound of coal, thus securing the greatest economy. These very same highly-educated individuals who designed these engines forget that all the power comes from the pound of coal and pay little attention to how that power is transmitted from the coal-pile to the engine. It is just as essential to good economy that the boilers should have the very highest initial or furnace temperature and the highest possible steam-pressure and the lowest possible chimney temperature as it is for the engine to be economical under similar conditions of high initial pressure and temperature and low terminal temperature.

Experiment has proved that bituminous coal requires 150 cubic feet of air per pound of coal for good combustion. An excess of air results in a waste of heat which it carries into the flues and chimney, and often a greater loss in an insufficient supply to produce good combustion.

In my experience, for steam plant boilers carrying 80 to 160 pounds of steam, I find that at least 20 pounds of bituminous coal should be burned per square foot of grate per hour, and the air spaces of the grates should not be less than 50 per cent. of the grate area and the draught-pressure not less than 2½ inches of water. If the grate surface is so large that only 10 pounds of coal are consumed, it would be more economical to reduce the grate surface and burn not less than 20 pounds with good draft, thus securing a good combustion. The same weight of coal burned on a large grate would not be as economical on account of low temperatures. The temperature of the furnaces should not be less than 3500° and the ratio of the draft area through the tubes or flues should not be less than one-sixth nor more than one-fourth of the grate surface, and the proportion of heat surface to grate surface should be at least as 35 to 1.

Under the conditions just stated boilers should be fired very economically, whether done by mechanical means or by hand. I have noticed in firing marine boilers on the Great Lakes that the firemen spread their coal evenly over the entire grate at each firing and they produce steam very economically, while firemen on coastwise steamers will pile up the coal just inside the furnace door and as it becomes coked will rake it back over the incandescent fire and grate with equally as good but no better results in the way of economy than obtained by the lake firemen. Both of these ways of firing are equally good, but in all cases the grate-bars should be entirely covered and the amount of air required above the grate should be admitted from above instead of below the grate.

Different grades of bituminous coal require different methods of firing, and by a little experiment the experienced fireman soon finds out and adopts the best method of firing, and in all cases he should keep his flues and tubes clear of ashes and soot, as well as his fires and grate-bars. In firing anthracite coal, the coal must be spread evenly over the grate in all cases, and, like bituminous coal, must be burned at a high temperature with good draft.

The steam-users should see to it that all parts of their boilers and settings are of equally as good proportions for strength and economy as their engines, employ good, intelligent firemen as well as engineers, and see that both produce good indicator-cards. By a little attention in this direction steam-users will themselves soon become experienced firemen, and engineers and can readily tell whether the firemen and engineers are doing their duty.

THE TRANSMISSION OF POWER.*

By Carl Hering.



ELECTRIC railways a year or two ago was the most prominent branch in the later developments in the field of electrical engineering, and the almost phenomenal growth of this branch is known to all who have given the subject any attention. Just as that was the leading subject during the past year, so the subject of the transmission of power in large quantities over great distances seems likely to be the chief field of development in the near future, a bold beginning having been made during the past year in the form of a very successful public experiment made at Frankfort, in Germany, on a scale far beyond anything before attempted. I am informed that much attention has been given by the promoters of the Niagara Falls power plant to this experiment at Frankfort, and its success will doubtless lead to the adoption of the same or a somewhat similar system for the Niagara-Buffalo transmission.

In order to appreciate more readily that the advantages of electrical transmission over other methods are well founded and are not mere vague claims made by its advocates, let us review briefly the other methods, all of which have been in use much longer than the electrical one and have had a chance to show their limitations. Most of these are almost without a rival in their own narrow fields, but when it comes to transmission over long distances, the electric method stands almost alone.

The most prominent method of transmitting power is by means of shafts and belts, but although this is one of the best for very short distances, it need not be considered at all for anything over a couple of hundred feet at the most. In an electric-light station in Rochester there is a belt 175 feet long and a shaft 200 feet long, and there are doubtless a few other exceptional cases like it, but it requires peculiar circumstances to make this practicable for even such a limited distance. Even for the short distances in workshops, shafts and belts have already been, and are rapidly being replaced, in many factories by individual motors placed in the immediate vicinity of where the power is required, and having their power transmitted to them electrically, which shows that even for such short distances electrical transmission encroaches on the field heretofore occupied entirely by the shaft and belt transmission. The only modification of the shaft and belt system adopted for longer distances is by wire-rope transmission. This is an old, well exploited system, and its narrow limits are already well known. The poor efficiency, the liability to stoppages, and the great increase of cost with distance, are very much against it for long distances. The fact that it takes a two-inch rope, running at a speed of 2000 feet per minute, to transmit only 36 horse-power, is sufficient to show the impracticability of this system for long distances or large powers. A significant fact is that in Switzerland, where this system is used perhaps more than anywhere else, it is already at present being rapidly replaced by electrical transmission. Another fact which is significant is, as I am informed, that rope transmission is not being considered at all by the promoters of the great Niagara Falls plant.

Transmission by water direct is limited to locations which are peculiarly favorable and is not general enough to be considered here. In Zurich there is a high-pressure reservoir located on a neighboring mountain, the water from which is used for power purposes in the city. There are doubtless other similar cases,

* Paper read before the National Electric Light Association.

but they are all limited to peculiarly favorable locations, as well as to comparatively short distances. Even in Zurich they are now installing an electrical plant, from which power is to be distributed.

Transmission by steam is of more general application, but the expense of the piping, the attention it requires, and the loss in the condensation, all limit its practicability to within a comparatively small radius, probably well within the radius of a mile at the most. It is in successful use in the city of New York, but its introduction does not appear to be making very rapid progress.

Transmission by gas as a fuel is in successful operation for very long distances of over 100 miles, but it is limited to localities where natural gas is found and its supply is, I am told, very uncertain.

Transmission by compressed air is perhaps the chief rival of electrical transmission, with which it shares many advantages over all the others. It is at present used chiefly in mines, where it is still a very successful rival of electricity, but from present appearances it is likely that it will gradually be replaced by the latter method. In Paris there is a large central station for the distribution of compressed air, and it seems to be in successful operation. It does not appear, however, that the advantages over electrical transmission are so great that it will not soon be replaced by electricity. Its introduction is not making the rapid strides that the introduction of electrical transmission is already making. Its efficiency as compared with electricity will be shown very well at the Niagara Falls power plant, where, I understand, a compressed-air system is to be introduced in competition with electricity. One of the disadvantages for power purposes is in the fact that when the compressed air expands in the engines it generates cold to such an extent as to seriously affect the working and the lubrication of the engine. It appears that fires must sometimes be built to heat the air before it can be used at all in the engines; the advantages over a boiler and a steam-engine are thereby greately reduced. From a paper of Professor Unwin it appears that the transmission of power by compressed air is practicable to a distance of at least 20 miles. It seems that 10,000 H.P. can be transmitted to a distance of 20 miles in a 30-inch main at 132.3 pounds per square-inch pressure, with a loss of pressure of only 12 per cent. The efficiency of such a plant is said to be 40 to 50 per cent. if the air is used cold, and 59 to 73 per cent. if the air is reheated. Mr. Coleman Sellers, one of the Niagara Falls Company's advisory committee, states in a recent paper that experiments were tried by a Mr. Saunders, of New York, of heating the compressed air at the receiving end by combustion within the mains; the result, he states, leaves little to be desired, as the product of the combustion is added to the quantity of compressed air, while the heated air and gas also increase the efficiency.

A very good idea of the relative efficiencies of several of these systems may be obtained from the following table by Beringer, giving the efficiencies for different distances:

EFFICIENCY IN PER CENT.

Distance in miles.	Hydraulic.	Pneumatic.	Wire rope.
½	50	55	91
1	49	54	85
3	41	51	61
5	37	50	43
10	26	43	21
13	18	39	11

The most usual and extended method of transmitting power, if so it may be called, is that of transporting the coal itself from the mines to the manufacturing cities. Although this is the system which is by far the one used most extensively, the objections to it are such as to offer great inducements to other competing systems. Even in Philadelphia, which is not far from the coal regions, the price of a ton of coal is said to be doubled by the cost of its transportation from the mines to the boilers in the city. In engineering terms this means an efficiency of 50 per cent. in the transmission only. An electrical system with such a poor efficiency in the line would

scarcely be considered for a moment, and yet, strange to say, we are still transporting most of our power on the railroads in the form of coal and utilizing it in small individual boilers and engines, the efficiency of which is so low that even an amateur electric motor builder would be ashamed of his motors if they did not give a better efficiency.

It will be seen, therefore, that with the exception of compressed air and the railroads, the field is quite clear from rivals for electrical transmission, and that most of the disadvantages attending other systems do not apply to electrical transmission. Even in the two excepted cases, there are many advantages in favor of electricity, and it is probably only a question of time when they, too, will be replaced by electricity. Perhaps the most serious objection to electrical transmission is that it is new, an objection which is often a much more serious one to overcome than many engineering difficulties. If capitalists were all engineers and were not hampered by prejudices against new departures merely because they are new, what enormous strides engineering would make.

Coming now to electrical transmission, let us see which of the various methods stands chance of success for long distances. To be successful at all for long distances requires, beyond question, the use of very high potentials, as otherwise the cost of the line will make it impracticable. If continuous currents are to be used, they must be generated directly by the dynamo at that high potential, as there is no means at present known for converting a low-tension continuous current into one of high tension without the use of moving machinery; continuous currents would therefore require that very high-tension currents be produced directly from a dynamo with a commutator. Long experience and frequent attempts have shown that it is not practicable to exceed five or six thousand volts at the very most on continuous current dynamos, and even then there are many objections. As this would be a comparatively low voltage for long-distance transmission, continuous current systems stand very little chance of being used for more than comparatively short distances. Another disadvantage is that the motors also must be run at this high potential, unless the current be transformed by a motor dynamo, which is awkward and expensive, as it involves the use of moving machinery requiring attendance. The starting of a motor at such high potentials also introduces difficulties. A point in favor of continuous currents is in the fact that the line is not charged and discharged continuously.

The field is therefore left tolerably clear for alternating currents, who owe it to two features, one that the alternating current dynamos require no commutator, and the other that such currents may readily be converted from a low tension to a high tension and the reverse with but a small loss of a few per cent. in each transformation. An alternating current dynamo for generating low potential currents is the simplest kind of a dynamo, and a transformer requiring no moving machinery is a very simple thing to take care of, if, indeed, it required any attention at all. Simplicity alone, therefore, is very much in favor of alternating currents.

The only serious objection to the use of simple alternating currents for the transmission of power is that they are not so suitable for running motors as direct currents are. There is a class of motors called synchronous motors, which are, as a rule, simple alternating current dynamos used as motors, like in the case of direct currents. These must be run at a speed which must synchronize with that of the dynamo as precisely as if coupled to the shaft of the dynamo. They run very well after they are started, but many of them come to a dead stop if overloaded sufficiently to retard their speed below that of a synchronism, even if retarded only to a slight amount. Their chief fault, however, is that they cannot be started readily; furthermore all the load must be taken off before they can be started at all. Various methods are used to start them, but although they accomplish the object they can hardly be termed satisfactory solutions of the problem, at least as far as they have come to my notice. This makes them unfit for many purposes, as elevators, street cars, shops, etc. When there is only one large dynamo, which is started, say only twice a day, it can be

done by a small inefficient motor or by starting both the generator and motor together, or by some other similar means, but when it concerns the distribution of power as distinguished from mere transmission, this disadvantage becomes of great importance. But this objection may not continue to exist very long, because with the amount of attention given this subject at present, it is not unlikely that some solution will be found before long, if it has not been found already. Several methods have already been devised for overcoming it, one of which was shown in the Frankfort transmission. Others are being at present worked out, among which may be mentioned that of Mr. Stanley and others; also that of Leblanc, which, I understand, is being experimented with on a large scale in the interests of the Rothschilds, of Paris. It is therefore likely that before very long this problem also will be solved by several methods so as to leave very few objections to the use of alternating currents.

One of the prominent features of the Frankfort transmission was that this motor problem was solved, as motors were there run, not only with the same ease with which continuous current motors are run, but with additional advantages which make them far preferable even to the best continuous current motors. The only objection to this system was that three wires had to be used in place of two, an objection which appears to be in many respects small as compared with the advantages gained.

There are in general two methods for transmitting to great distances by alternating currents. One is to generate the high tension currents directly at the dynamo; this is the system used at the Ferranti station in Deptford, London. At the distant end these currents are then transformed to low-tension currents suitable for distribution to consumers. The second system is, to generate low-tension currents at the dynamo, then to transform these at the dynamo station into high-tension currents by means of transformers, which high-tension currents are then sent through the line to the distant station, where they are transformed a second time back to the low-tension currents; this is the method which was used at Frankfort. The advantages of the former is that there is only one transformation, but a disadvantage which appears to outweigh the objection to an additional transformation is that the high-tension current must be generated on moving machinery and that it must be controlled by switches and other apparatus, which must be handled by the attendants. The dynamos and switches are thereby rendered very much more complicated, and, as they must be handled, there is a constant source of danger to the workmen. This source of danger and the complications are overcome almost entirely by the second system. In the one used at Frankfort the dynamo was the ideal of simplicity in its construction, and the high-tension circuit contained, with one exception, no switches or any apparatus whatsoever that required to be handled.

To recapitulate, it appears probable that the solution of the problem of long-distance transmission will be solved by the use of high-tension alternating currents originally generated at a low voltage, then formed into a high voltage, then sent over the line and finally transformed back to a low tension; this will furthermore be done by some system which will enable motors to be used on the circuit. The system exhibited at Frankfort was such a one and it appears to have been a perfect success in every way. It seems therefore that the problem has not only been solved, but also demonstrated by a practical illustration on quite a large scale.

Among the transmission of power plants in this country may be mentioned the following: One at the Dalmatia mine in California, in which the power is about 100 H.P. transmitted about one and one-half miles at 1800 volts by direct current. Another in Virginia City, Nev., in which about 500 H.P. is transmitted a distance of about one-third of a mile, with an efficiency of 70 per cent. Another at the Calumet & Hecla mines, in which 400 H.P. is transmitted about one and one-half miles at about 1000 volts, and at an efficiency of 73 per cent. These are all direct current systems (Brush). Another was installed by the Westinghouse company at Telluride, Col., in which about 120 H.P. are trans-

mitted two and three-quarter miles at 3000 volts, and at a commercial efficiency of 75 per cent. This is of special interest, because it is an alternating current plant, in which the motor and dynamo must run synchronously. The difficulty of starting the motor is overcome by the aid of a small motor of 10 H.P., which is first run to bring the large one up to speed, after which it will remain in synchronism with the generator. The cost of this plant, exclusive of erection and line, is said to have been $10,000, or about $100 per H.P. delivered.

A fair idea of the cost of transmission of power plants may be obtained from the following table of figures given by the Oerlikon company, and taken from plants actually installed by them, mostly in and about Switzerland. The table was copied from a paper read by Mr. Saunders Morris at the Engineers' Club of Philadelphia.

COST IN DOLLARS.

Distance in miles.	H.P. delivered.	Generators.	Motors.	Line.	Total.*	Per H.P. delivered.
6.25	11	647	540	2,350	4,700	42.60
.43	510	.....	.....	.....	33,250	65.30
3.75	220	5,190	4,700	3,135	14,500	66.20
1.56	150	3,720	3,525	1,615	10,020	67.20
.56	71	2,155	1,960	294	5,100	71.60
7.87	85	3,135	2,741	2,155	9,220	108.50
2.20	51	1,761	1,567	1,469	5,595	109.40
5.00	41	1,174	980	1,682	5,000	121.10

*This includes regulating apparatus, instruments, poles, insulators, lightning arresters, erection, and supervision.

The Lauffen-Frankfort plant has already been described in detail in my reports in the *Electrical World;* I will therefore give here only a brief mention of the chief features, referring those who desire further details to those published descriptions. For an opportunity to visit this plant I am indebted to this journal, in whose interests I went abroad during the past summer to make reports on this as well as other European plants.

This experimental plant was erected by the joint co-operation of the Allgemeine Elektricitaets Gesellschaft, of Berlin, and the Oerlikon Company of Zurich, the chief engineering features being due to their respective engineers, Mr. Dobrowolsky and Mr. Brown.

The main object of this plant was twofold,—first, to test and demonstrate to the public the feasibility of using very high-tension alternating currents on bare overhead lines; secondly, to show the practicability of a modified alternating system especially adapted for running motors. The former feature was due to Mr. Brown and the latter to Mr. Dobrowolsky. It was an experiment in so far as it was at first not known whether such very high potential currents used on overhead lines would develop any new and grave difficulties, which were predicted by some mathematical electricians, involving capacity and induction effects. These fears were not realized, however, or in the terse language of Mr. Dobrowolsky, "the losses in the line all followed Ohm's law." The experiment demonstrated that with the use of carefully made and proportioned porcelain insulators containing oil, such high potentials can be used successfully on bare overhead lines. Strange as it may seem, one of the unexpected serious difficulties experienced on a line with similar insulators, was that such large white insulators formed tempting targets for the small boys to thown stones at, because a "good shot" from one of the little rascals was awarded by the pleasure of seeing the insulator flying to pieces, ringing like a bell.

The plant consisted in general of a dynamo of exceedingly simple construction generating a large current, but of only 50 volts. This was led through the switchboard with all its accessory apparatus and was then transformed by a step-up transformer into a small current of 16,000 volts. This was led through bare overhead wires a distance of 108 miles, where it was again transformed back to a low voltage by step-down transformers. It should be noticed that the currents at the dynamo and the switchboard, where they had to be handled, were only 50 volt currents, thereby avoiding all possible danger to the attendant besides facilitating greatly the construction of the dynamo. In this feature it differed characteristically from the system used by Ferranti in London, in which the dynamo and

switchboard were in the high potential circuit, the dynamo generating the high voltage directly. The Frankfort system was furthermore grounded in such a way that even in the case of a cross with the high-tension circuit the voltage at the dynamo or switchboard can never exceed 50 volts above the ground. The second feature of this plant is, that it enables motors to be run with the same and even greater ease than continuous current motors. It therefore solves the problem of distribution as well as of transmission of power. It should be clearly understood that it was to solve the motor problem that a certain modified alternating current system, known as the three-phase system, was used. This system involves the use of three wires throughout in place of two, but it not only overcomes the difficulty of the distribution of power and the starting of motors, but it goes farther, because such motors are very much easier to run and are simpler in construction than the best continuous current motors, a feature which counterbalances to a great extent the objection to the use of three wires.

Time will not permit a detailed discussion of this three-phase system here ; it will suffice to say that it consists of three simple alternating currents,—one in each wire,—the waves or impulses in the three wires following each other in succession similarly to the relative motions of the three cranks of a three-cylinder steam-engine, or the pistons of a three-plunger pump. Such a set of currents produces a *rotating* magnetic field, while the simple alternating current produces merely an *oscillating* field. The rotating field furthermore has a definite direction of rotation. It is this feature of a rotating magnetic field as distinguished from an oscillating one which renders it particularly well adapted to run motors. The ordinary simple alternating current motor may be said to be analogous to a steam-engine with one crank, having its slide-valve operated by an independent rapidly running engine ; it has a dead point from which it will not start, but after it is up to speed it will run very steadily. The rotating field motor, on the other hand, is analogous to a three-crank engine operating its own valves. There is no dead point, and it can start itself, even with full load.

As to the priority of invention of this rotary field system, I will only say here that Ferraris and Tesla seem to have invented it originally and independently of each other. Just in what respects Dobrowolsky improved it is hard to tell until we know how far Tesla developed it. It will suffice to say here, that as modified by Dobrowolsky, the motors appear to be an undeniable success.

In conclusion the following figures regarding the Lauffen-Frankfort plant, together with a few illustrations of the details, may be of interest.

The small town of Lauffen is situated on the river Neckar, in the mountains, 108.6 miles south of Frankfort, and not far from the city of Heidelberg. There is a large water-power there, 300 H.P. of which is to be transmitted electrically to the manufacturing town of Heilbron at 5000 volts by this system. The turbine and dynamo of this plant were loaned for the Frankfort experiment. The turbine is horizontal, has a speed of 50 revolutions, and can develop 300 H.P. It drives a single dynamo by conical gears. The dynamo is of exceedingly simple and mechanical construction, has a speed of only 150 revolutions, and is capable of generating three alternating currents of 50 volts above their common connection, and about 1400 ampères each, or a total of about 200 kilowatts. The number of alternations is 40, which is purposely made very low. This current passes through the switchboard and regulating apparatus to a three-core transformer of equal capacity. The ratio being 160, it is transformed up to about 12,500 to 15,000 volts, measured between any two of the three wires, and down to four or five ampères ; by connecting two of these with their primaries in multiple, and their secondaries in series, they will generate 25,000 to 30,000 volts.

An interesting feature about this system is that although the three currents have different phases, they need no separate return leads, because the nature of the currents is such that each acts as a return current for the other two in multiple arc. The three circuits are therefore merely connected together to

a common terminal, after they have passed through the dynamos, transformers, and lamps. This terminal we will call the neutral point. This neutral point was grounded throughout the system, in the low-tension as well as in the high-tension circuits, and at both ends of the line. No current, however, will flow through the ground when the plant is working normally.

The line consists of three bare, hard-drawn, copper wires, 4 millimeters in diameter (slightly less than a No. 6 B. & S. wire), having a resistance of about 2 ohms per mile. The distance being 108.6 miles, the resistance of each wire is about 217 ohms, which, with 5 ampères, makes a loss of about 1000 volts on each of the three lines. The lines were run on poles with one cross-arm 16 feet above the ground, the wires being one meter from one another. There were 3227 poles, at 200 feet spans; each pole had a skull and crossbones painted on it to indicate the sure fate of anyone who could not keep his hands off. There were 3000 large porcelain insulators, 8 inches in diameter, made in two parts and with three oil grooves, and 6500 small ones, made in one piece and with one oil groove. The only apparatus connected with the high-tension circuit was the fuse wire and a short-circuiting device to replace the switches for opening the circuit. The fuses for each of the three lines consisted of two copper wires in parallel, each .15 millimeters in diameter (between Nos. 34 and 35 B. & S. gage) and 2 meters in length. They were stretched between two poles outside of the building. They were exploded (one can hardly apply the term "blown") several times to test their effectiveness. Even to an electrician it seems strange to think of several hundred horse-power being transmitted through a few wires about the size of a hair! The short-circuiting devices consisted of pieces of bare wire shaped like a V inverted, suspended directly over the line wires. These were placed at very frequent intervals along the line. In case of any danger or interruption, or in case the line must be handled, this wire is lowered by a string, and drops on the line wires, thereby short-cutting the line, which blows the fuse and opens the circuit. This is a very cheap and effective substitute for a switch, which would be dangerous to handle in a 30,000 volt circuit; futhermore there is absolutely no possibility of a current being on the line when this device is down.

Both the high-tension and low-tension circuits were carefully grounded at both ends at the neutral point, that is, at the common junction of the three wires. This makes the system perfectly safe, for in no case can the voltage on the low-tension circuit be greater than the normal low voltage. In case of a ground on the line, or a cross between the high-and-low tension circuit, the fuses will blow.

Arriving at the receiving end, at the exhibition at Frankfort, the high-tension current was transformed down to about 75 volts measured between any two of the three wires. Some of it was used to illuminate one thousand 16 C.P. lamps on the exhibition grounds, consuming 58,000 watts, and some was used to run a 100 H.P. motor, which drove a centrifugal pump, the water from which formed an attractive waterfall on the exhibition grounds. The average voltage used on the line was about 16,000 volts, and the greatest amount of power, I am told, was about 180 H.P. This was not because of any failure to be able to transmit more, but merely because that was the full capacity of the bank of lamps and the motor.

The official tests are not yet completed, but from careful commercial measurements it was found that the efficiency from the dynamo current at Lauffen to the lamps at Frankfort was 72 per cent. when about 80 H.P. was transmitted, which is very satisfactory. It is furthermore probable that accurate measurements will increase rather than decrease this figure. It should be noticed that this was the efficiency for only 80 H.P. From this efficiency must be deducted the loss in the generator and that in the motor in order to get the total. After the exhibition closed, the plant was also run at 30,000 volts; during that test one of the insulators failed. The plant was run in all kinds of weather without apparently any appreciable increase of the loss on the line. It was

furthermore found that the predicted heavy losses, due to the condenser action, did not exist, and that for practical purposes these losses follow Ohm's law. It will be remembered that this was one of the uncertain features, the existence or non-existence of which this experiment was to prove. As the distance was far beyond that at which power will, in practice, be carried, say 30 or 60 miles, this experiment demonstrates that such a transmission is entirely feasible at distances met with in practice.

The Oerlikon company gives the following figures regarding the cost of the plant: Assuming that 300 H.P. is developed at Lauffen, and that all the energy received in Frankfort was converted into light, the cost of the plant per effective horse-power, measured at the terminals of the lamp, will be about $282, of which $236 is for the line alone. These figures appear high, but it must not be forgotten that in this particular plant there were conditions which would not be likely to occur in practice—namely, relatively small power on the one hand and exceedingly great distances on the other, both of which factors naturally increase the cost per horse-power.

It may be of interest to add here that Mr. Dobrowolsky, of the Berlin firm, states that he would be willing to bid on the contract to transmit 1000 or 5000 H.P. from Niagara to Chicago, a distance of about 500 miles. He proposes to use 40,000 to 50,000 volts and claims that an efficiency of 60 to 75 per cent. could be obtained without difficulty.

THE engines illustrated on another page have recently been constructed by Messrs. Hick, Hargreaves & Co., Soho Ironworks, Bolton, for a cotton-mill belonging to the Kampenhofs Aktiebolag, Uddevalla, Sweden, to take the place of a pair of Woolf beam-engines supplied by the same makers about thirty-five years ago.

As will be seen from the illustration, the new engines are horizontal, and of the four-cylinder double-tandem type, the high- and one low-pressure cylinder working on one crank, and the intermediate and the other low-pressure cylinder on the other crank. The high-pressure cylinder is fitted with the makers' well-known Inglis & Spencer's Corliss gear, the intermediate-pressure cylinder with a piston-valve, and the two low-pressure cylinders with plain slide-valves. All the cylinders are jacketed with steam at boiler-pressure, and are lagged with composition and felt, cased with planished steel. The steam on its way from the high-pressure to the intermediate-pressure cylinder, and from the latter to the low-pressure cylinders, passes through two receivers, also jacketed with steam at boiler-pressure. There are thus six jackets to be drained—four cylinders and two receivers—and the makers, believing that the efficiency of jackets is largely dependent on the thoroughness with which they are kept clear of water and air, have devoted considerable attention to this problem. In present engines the jackets are drained in series, the combined drain-water from all passing into a receiver, which, standing on the engine-room floor, and being provided with pressure- and water-gages, gives the attendant a much better chance of keeping the jackets efficiently drained than where each jacket has its own trap placed out of sight under the floor, and too often out of mind. The engine is provided with very complete lubricating appliances, including oil-pumps for the crank-shaft bearings, and with indicating gear for all the cylinders. The power of the engine is transmitted by a steel spur-wheel bolted to the fly-wheel, but which was not in position at the time the photograph was taken from which our engraving is made. The surface condenser is of the marine type, the water making two passes through Muntz metal tubes fitted in Muntz metal tube-plates, and packed with "Hall" joints. To the condenser are attached the air, circulating, feed, and jacket drain-pumps, all four being worked by levers of the piston-rod of the intermediate pressure cylinder. This description and illustration are taken from *Industries*, of London.

TYPICAL AMERICAN CRANES.

By Henry Harrison Suplee, Member Am. Soc. M.E.



THE use of cranes in America not many years ago was limited to the clumsy wooden-frame jib-cranes with primitive winch mechanism and rough gearing which were used in foundries and erecting-shops, and the comparison which has forced itself upon the observant engineer who had the opportunity of seeing what had been done in Europe could not but be most unfavorable to the practice of this country.

To-day the numerous forms of cranes and hoisting machines which are in use everywhere in the United States attest the progress which has been made in this branch of machine design; and although many of the cranes which have found widest acceptance here are based upon European practice, yet at the same time the demands of American service have compelled such important modifications in design and detail as to make them practically new machines. In many cases the cranes which are here shown are strictly American in conception, being the outgrowth of conditions existing here only, and in all the forms the development of what was originally little more than a rough derrick into a highly organized machine will be most evident.

For many purposes the rotary type is still the most available form, but the modern American jib-crane is a very different machine from its predecessor. The wooden framing is replaced by wrought-iron channel-bars and I beams, proportioned with the same care to resist stress as are the members of a bridge or roof truss. Instead of a crude winch, with small, smooth barrel, and unprovided with safety mechanism, the modern crane is furnished with a grooved chain drum so large that the chain is never compelled to ride upon itself, while the old and dangerous practice of lowering by throwing the ratchel pawl out of gear and exposing the operators to the danger of the sudden flying back of cranks is no longer followed, some form of safety-check mechanism being employed. A safety winch is so constructed that the cranks must be turned backward to effect lowering, and should they be let go they will immediately come to rest; and any form of dispatch lowering should disconnect the crank-shaft and permit only the drum and its gearing to revolve while under control of the brake. In these points and in the careful proportioning of all parts to their respective duty the American jib-crane may fairly be considered a typical machine.

In the feature of safety-lowering alone the American hand-crane, whether jib, pillar, bridge, or whatever type, is far in advance of its predecessors, and the removal of apprehension in the men of danger from accident in itself adds greatly to the efficiency of the machine, since lowering can be effected with an ease and rapidity which might lead to danger in the absence of automatic checks. The hand jib-crane will always be a favorite form for foundry use, the smooth motion of translation about the center of revolution and the complete and satisfactory control of all the functions making it especially popular for this use, and if the choice of the most popular type of crane were left to the foundrymen there is little doubt that the jib-crane would be selected. Even for heavy service the hand jib-crane is much used, although this type of crane readily lends itself to the application of power, and steam-power jib-cranes are in extensive use.

In the application of steam-power to rotary cranes the influence of American ideas and the freedom from prejudice is clearly shown. Various forms of transmitting mechanism have been successfully

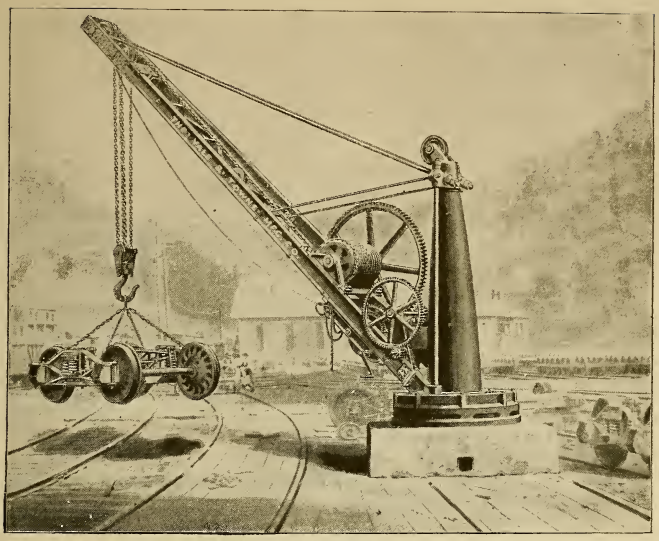
applied to place all the functions in connection with the motive-power and ingenious and effective clutches and gear-trains introduced. The best modern practice is, however, inclined toward the subdivision of the motive-power, and "three-motor" cranes, having an independent, double-acting steam-engine for each function, represent the latest designs in power-cranes. The multiplication of engines is offset by the removal of most of the mechanism of transmission, and the results are most satisfactory in practice. The use of trussed frames is also in the line of economy of material and absence of superfluous weight in manipulation, in itself a characteristic of distinctively American practice. For light service at fixed radius a favorite form is that in which a direct-acting steam cylinder of long stroke is used, the travel of the chain being increased by reduplication over fixed and movable sheaves when necessary.

These forms are all adapted to indoor service, the mast being supported at the top by the framework of the building and the lateral stresses being transmitted to the walls. Radial cranes for outdoor use are coming into extensive use in this country, however, and, although the pillar-crane can hardly be called an American type, yet it has received most distinctly the impress of American practice in this country. The winch mechanism is marked by the ample provision in the winding drum for all the chain required for the given hoist, the whole amount being taken up in a single series of wraps. The use of safety ratchet-check devices effectually prevents all running back of the cranks and the load is sustained at all points, it being absolutely necessary that the cranks be turned backward to cover the load.

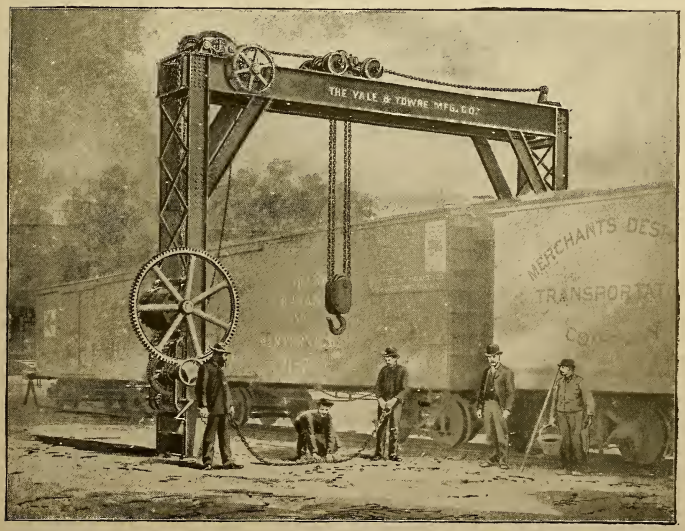


HAND JIB-CRANE FOR FOUNDRY USE.

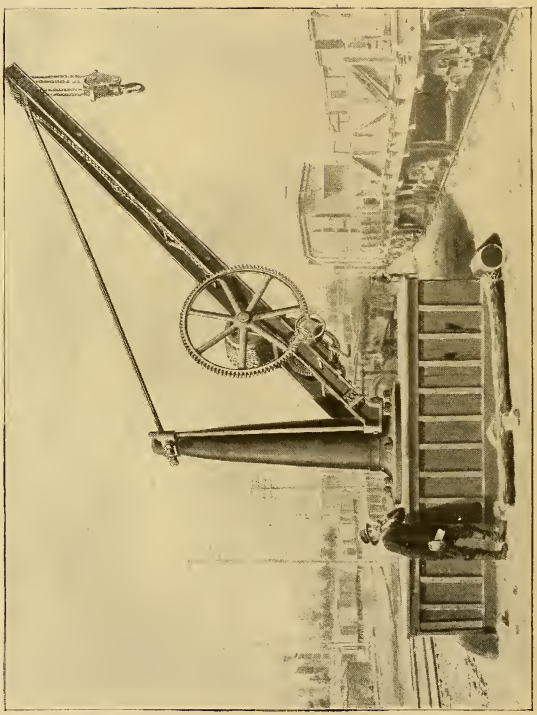
In Europe the pillar-crane is a favorite type, largely on account of its convenience and suitability in connection with the massive masonry quays and docks, where the foundations are at hand and the duty of a simple character, such as transferring merchandise from trains to vessels and *vice versa*. In this country, unfortunately, the wharf construction is



HAND PILLAR-CRANE WITH AUXILIARY WHIP-HOIST.

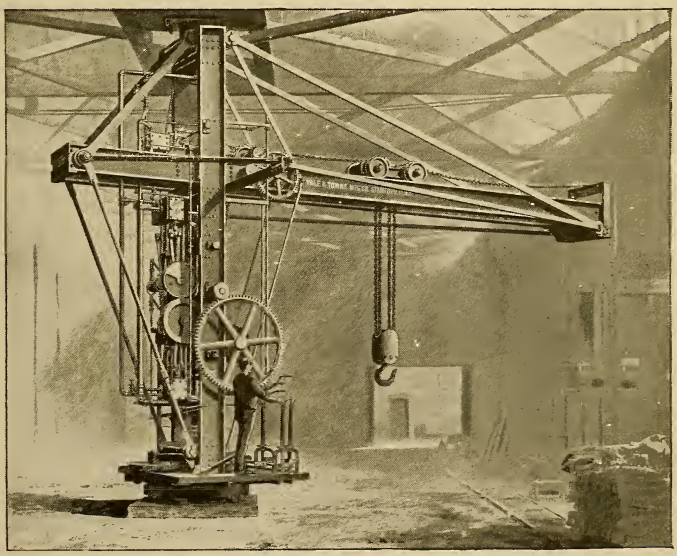


BRIDGE-CRANE.



HAND PILLAR-CRANE.

sadly lacking in the solidity so general abroad, but pillar-cranes have found ample acceptance for railway service, and as their value and convenience at freight stations is appreciated they are undoubtedly destined to come more and more into use. The absence of suitable facilities for handling merchandise is one of the points in American railway practice which is open to criticism, and in the close competition for business the provision of such facilities appears to have been often overlooked as a factor in in-



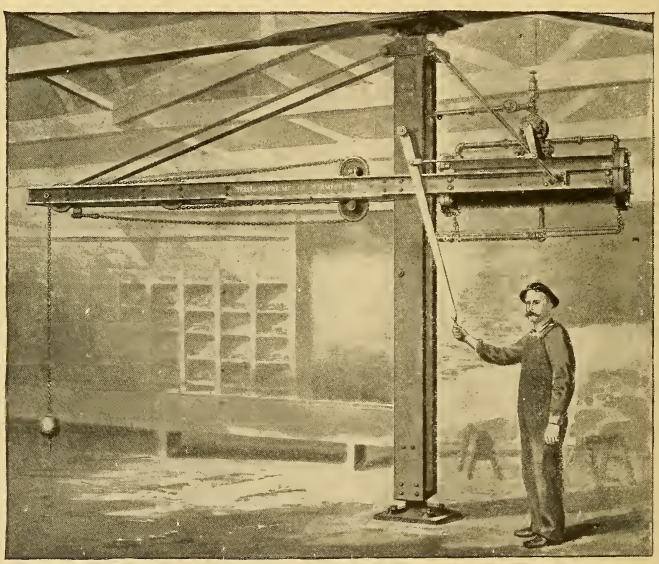
STEAM-POWER JIB-CRANE (THREE-MOTOR TYPE).

fluencing trade. In many instances heavy merchandise is shipped by undesirable routes, merely because it must be sent from the station where there is a crane which can handle it, in spite of the fact that great advantages might otherwise be obtained from competing roads if the bulky or heavy piece were once safely loaded upon the train ; and in this respect at least American practice has not yet attained the point existing elsewhere. Pillar-cranes, although eminently adapted for this service, are not the only

available form, and in some situations the bridge-crane is to be preferred. This is, of course, a totally different type, being a rectilinear crane, but in principle it is not greatly different from a jib-crane as to hoisting and and trolley gear, but the jib—in this case the bridge—is supported at its outer end, and hence the whole structure is stationary and its functions are limited to hoisting and trolleying. It is a most desirable form for railway freight stations, and in its present form may be considered as an American type also. A bridge-crane may be constructed to span two or more lines of track or roadway and is especially adapted for situations where it would be difficult to obtain suitable foundation for a pillar-crane of equal capacity, while for handling bridge-work or similar long material two bridge-cranes placed near each other form a more useful combination.

It is a frequent occurrence for foreign engineers visiting this country to express surprise at the increased duty which is

obtained here from machines of similar forms to which they are accustomed in Europe. This is especially true of cranes which have been modeled, perhaps, after foreign ideas but adapted to American practice. The service of a crane—or, indeed, of almost any machine—is dependent upon a number of factors besides that of mere load, and when increased rapidity is to be considered, or yet more, increased frequency of application of the full load, the severity of the service for cranes of the same nominal rating will sorts is evidence of this success. In the old-time machine-shop the force of laborers was proportionally much greater than at the present time, and this change is undoubtedly due to the more general introduction of these labor-saving machines. In the absence of proper facilities for handling materials much time was formerly lost, and very often skilled workmen were obliged to leave their machines to "lend a hand" in some heavy lift. In like manner a large gang of men, otherwise necessary at freight



DIRECT-ACTING STEAM JIB-CRANE.

be found to vary between very wide limits. So also the proportioning of framework is now based, not on ultimate strength, but on present stiffness, and the problem of meeting the conditions which daily present themselves in new and varied forms makes the designing of cranes for American service a very different one from that existing elsewhere.

That this problem has been well met and successfully handled is now an accepted fact, and the rapidly-extending use of cranes for handling materials of all stations, has in very many places been superseded by most effective and powerful cranes, sometimes acting singly, at other places in conjunction, thus at one time dispensing with much expense and saving still more valuable time.

The great and rapidly-growing group of traveling cranes, both hand and power, is of sufficient importance to be reserved for another paper, and with these will be considered also locomotive cranes, a form too little known here, although most thoroughly acclimated.

(To be continued.)

ELECTRIC LIGHTING FROM A FINANCIAL STANDPOINT.*

By Erastus Wiman.



THE evolution of progress on this continent would seem as if electricity was the flower and fruit. The stupendous change which in the condition of the human race has been possible by development on this side of the sea needed just such a revelation as is possible only in electrical science. A drama of such proportions, on a stage of such magnitude, by a people of such intelligence, illustrating such principles as self-government, such events as a material progress beyond all that the world has ever seen, needed above all things a new force, a new hint from the mysteries of the unknown, a new law of Nature as forceful as gravity, as helpful as heat, as widely diffused as air. Electricity thus takes its stand just at its right place in the marvelous procession of events in the human progress toward a higher and nobler life, which has been rendered possible by the discovery of America.

But in contemplating the progress made in the last century, and seeking to discover the influences and forces that have most contributed to the growth of wealth, to the comfort, safety, and happiness of the human race, as illustrated on this continent, it may be safely claimed that electricity, even in its early stages, has played a not unimportant part. It would seem as if in a country of such vast areas as is the United States nothing in the whole category of events would be so highly beneficial as a means of instantaneous communication, and yet this vast boon of instantaneous communication was only possible by electricity.

Incidental to the unequaled usefulness of telegraphy in the marvelous progress of the country has been its contribution, in a special degree, to the railroad service, which to so great an extent has contributed to material growth, the increase of wealth, and to the comfort and happiness of humanity. The use of the railway telegraph has practically doubled the tracks of every single-track railroad on this continent, rendering the movement of trains so precisely, so rapidly, and so safely that without this facility of instantaneous communication the railroads would not have achieved half which by its aid has been accomplished.

But just as telegraphy had reached its perfect degree of usefulness in general purposes, as in the railroad service, shown by the perfect growth in electrical science, it was supplemented by a still more wonderful faculty of communication in the telephone. My friends, in all the series of wonders which the electrical world has revealed, this telephone is to me the most wonderful. To a layman like myself, who simply wanders along the outer edges of this magical land of discovery, this transmission by the aid of electricity of the human voice in audible and natural tones to great distances is of all things the most marvelous.

But another field of opportunity for the usefulness of electricity for the benefit of mankind has been found in its uses for the creation of light. It is a singular fact that so many ages had passed since the world began, and that only by the slightest degrees was the darkness which falls like a pall upon the earth mitigated. Many can even now remember, especially in country places, the tallow dip, the short sixes, the oil and spirit lamp, and the uncertain though mellow rays of the finished wax candle. It is quite within the memory of many men here that petroleum with its wonderful power of il-

* Paper read before the National Electric Light Association.

lumination was discovered, and all the world has since been blessed, not only by its illuminating power, but by the business skill and sagacity which, through the Standard Oil Company, has diffused this article so universally, so safely, and so cheaply, illustrating the high benefits of a well-managed monopoly as against the universal condemnation of that economic feature of the hour.

With the discovery and development of gas, of course, a vast change took place. But in the 60 years of its development, before it reached its meager perfection, there was the slowest kind of progress, so that it is only up to within the last half century that artificial illumination became at all general even among great aggregations, like cities and towns.

It remained, however, for electricity, and within our own lifetime, to beget a degree of success in this wonderful work of the creation of light that nothing else had ever yet achieved. It may be doubted if in the history of any science the same rapidity of movement has been made as in the adaptation of this form of energy to the highly useful and beneficial purposes of the creation of light. For instance, remote places adjacent to cities, to which a gas main was an impossibility, have been reached by an electric wire. Neighborhoods have been joined together, localities connected, and property increased in value by rendering communication at night secure and safe as in the day. In the application of the arc light to public works of great importance, like aqueducts, tunnels, and especially to manufacturing, numerous branches of business are susceptible of being carried forward 24 hours in the day, which without it would be impossible. Thus is doubled the capacity of many establishments and the earning power of many an investment. In all public places, as in theaters, halls, and in almost all business establishments, where business after the setting of the sun is essential, electricity is already beginning most effectually to supplement daylight and play a part almost as effective as the sun itself.

It will thus be seen that, so far as fulfilling the purposes of its manufacture, electric lighting is a definite and ascertained success. So far as experimentalization is concerned, nothing now remains to convince the public of its safety, of its effectiveness, of its healthfulness, and of its general adaptability to all circumstances. Hence, as an article of merchandise, the light furnished by electricity is just as much in demand to-day as wheat or corn, as beef or bread. So that this assemblage of electric-light men may congratulate themselves that, notwithstanding many difficulties and obstacles, they have, by the excellence of material, by its reliability and effectiveness, created an article of merchandise of real value, for which there is a strong demand.

It is true that in the creation of this article of merchandise, up to this period, there have been many mistakes. There has been a great waste of money, and if the past had to be lived over again there are not a few who would shape their policy in an entirely different way to achieve the result now reached.

The question of profit remains to be decided in very many localities. I have been favored during the last month or so with an enormous number of letters in response to a request for information as to the condition of the electric-lighting business all over the country. A great deal has been sent me of a confidential nature, and I can only give the general impression which the whole correspondence has made upon my mind. My conclusions are, first, that there is an enormous demand, only as yet partially developed and partially met, for electric lighting; second, that the public have been led to believe that it can be created for very little money; third, that in competition with gas an insufficient price has been asked for a light infinitely more brilliant, infinitely greater in candle-power, far more healthy, and, as a rule, far more safe; fourth, that at the start of many electrical plants the most meager and insufficient foundations were laid for a business requiring the utmost precision and the most perfect material.

It is these conditions, coupled with the rapidity with which inventions have followed one upon another, the constant reduction in the price of electrical machinery, the rapid growth of electrical appliances, and the radical changes and methods, which in six months would ap-

pear to be old in the history of a business which was so new and making such tremendous strides as to make it exceedingly difficult to maintain the expenditure on capital account within the original limit of corporations.

Looking back upon the past, it is easy enough to account for the difficulties, obstacles, and want of profit in many establishments, but if there is one thing more than another that has made the progress toward profit a difficult one, it is the mistaken apprehension of the public that electricity can be got for nothing. There is something so mysterious and occult, something so magical about electricity that the impression has got abroad that it is only necessary to press the button and, with the least exercise of skill, labor, or expenditure, the miracle is produced. The attempt to compete with poor gas, at a low price, with infinitely less illuminating power, was, of course, a necessity. But the public estimation of electricity has never yet reached the standard which it should have done. The slow introduction of the current into private houses is perhaps the best illustration of this condition. Even to-day, in some cities, it is thought the arc light can be had for 15 cents a night and the incandescent light for a mere song; $15 a year is slightly over a quarter of a cent an hour, yet for this, for 10 to 12 hours, a beautiful bulb of incandescence is expected at every street corner and in every remote suburb for almost less than it would ordinarily cost to burn a wax candle.

The public estimation of the cost of electric lighting has been allowed to prevail to an extent destructive of profit. There has been an hallucination prevalent that there was something miraculous about the production of electricity. The cost of coal, labor, and machinery has not entered into the calculation of either the ordinary city official or the private customer. The expectation that something would be produced for nothing, which inheres in the human mind as to the possibility of invention, has attached to electricity more than to any other element in the supply of human wants. The consequence is that in making new contracts, even to-day, there is the strongest disposition to get the prices down, not to what the article can be produced and paid for, but for the least possible amount, irrespective of profit and equally irrespective of efficiency. There is a true and false economy, and that is the falsest kind of economy that expects a public service at less than the cost of its output and a fair profit.

Having in the process of time developed a large demand for light, evidences of which are seen on every hand; having at the same time gone through a most unusual experience in not only creating that demand, but in the production of the article for its supply, a review is in order as to the present position of electrical securities and the prospect of profit. It may as well be admitted that there has been a serious and costly struggle, and that, taken as a whole, the result in the shape of a total profit on the total investment in electric lighting is not to be seen in the shape of dividends. There are, however, happily, exceptions to this general statement, and in the returns sent to me from all parts of the country there are a considerable number of companies whose career has shown that in electric lighting there resides the potentialities of a profit equal to that of any legitimate enterprise. The successful companies illustrate what it is possible to do, and though they may not be numerous in comparison with others whose record for profit is small or who report a loss, yet that money can be made continuously and rapidly out of electric lighting is clearly demonstrated. In order to cite an example of steady growth in revenue, and also to show the corresponding ratio of expense, I append the figures for seven years, from one of the most successful companies in the East, whose management has been characterized by the highest ability, and whose location and name it would hardly be proper to disclose. The figures are authentic, and show a record of which any man might be proud.

EARNINGS OF AN ELECTRIC-LIGHT COMPANY.

For 1885—Receipts		$30,768.70
	Expenses	24,901.54
	Net earnings	$5,867.16
For 1886—Receipts		$47,613.76
	Expenses	34,700.83
	Net earnings	$12,912.93

For 1887—Receipts		$57,750.71
	Expenses	34,691.85
	Net earnings	$23,058.86
For 1888—Receipts		$75,734.14
	Expenses	46,235.83
	Net earnings	$29,498.31
For 1889—Receipts		$135,254.08
	Expenses	94,178.69
	Net earnings	$41,075.39
For 1890—Receipts		$199,195.72
	Expenses	150,195 48
	Net earnings	$49,000.24
For 1891—Receipts		$247,679.88
	Expenses	187,092.77
	Net earnings	$60,587.11

The company commenced to pay dividends January 1, 1887, at the rate of 8 per cent., payable in quarterly dividends of 2 per cent., and have continued the same up to date.

Before closing the books December 31, 1891, we charged off from the earnings of 1891, for depreciation, $10,000 from the steam plant, and $30,000 from the electric plant. On January 1, 1892, the capital stock was $800,000; surplus, $90,000.

The above figures speak for themselves, and in the progress shown in receipts and profits there is contained a hopeful sign for many another company whose career up to this time has yielded an inadequate return. Indeed, to present a totally different picture, here is an extract from the letter of an esteemed Western friend that shows the ruins of a senseless competitive struggle and the folly of low prices:

"I am the president and manager of five electrical-light companies in this city, but *three* of which have actually survived financial pressure and bankruptcy. One of these three, with a capital of $150,000, fell behind nearly $100,000 in seven years, and last year the stockholders voluntarily came up with an assessment of $60,000 to save it from bankruptcy. Another, working under the strictest economy, is but barely able to meet operating expenses. Still the other, a foundling of the gas company, is, under exceptionally favorable conditions, and paying no salary to its executive officer, making a little money; after 18 months' operation, it last month declared a dividend of 3 per cent."

With such an experience it is no wonder that the gentleman writes as follows:

"I am aware that books can be kept so as to show an earning, but this is in many cases at the expense of a constantly depreciating capital investment."

These two extremes of success and failure tell the whole story of electric lighting in the past seven years. The companies that have succeeded have done so under favorable circumstances, with a freedom from ruinous competition, exacting good prices, and above all other requisites, with good management. If there is any department in human activity where brains and tact are required to a greater degree than any other, it is in the administration of an electric-lighting plant. This is evident, not only because there was a great lack of experience and knowledge of a business that was in the production of an article that was in a certain sense mysterious and unknown, but because there has been an amount of misapprehension as to its cost on the one hand and its value on the other hardly ever experienced regarding any article of merchandise.

Some attempt has already been made to account for a misunderstanding as to the cost of electric lighting, but it is proper to allude to the folly which has prevailed in selling it for less than cost. The insane competition with each other in localities where one company was needed and more than one was ruinous is well-nigh passed, but there remains the competition with gas companies and the effort made to constantly lower the standard of electricity to that of gas. It was perhaps essential that in the early history of the effort to use electricity as an illuminant, it was necessary to get down to the standard of the fumes of coal, and in order to show the superiority of one over the other, to yield for a time in the matter of profit. But so rapid has been the growth in the use of electricity, so immeasurably superior is the current to the fume, in health, in brilliancy, in beauty and attractiveness, that the time seems near when electricity can claim the rightful place, and demand the price just so much higher as it is an illuminant just so much better. An advance in price commensurate with the superi-

ority in the article produced would add largely to the earning power of electric-lighting companies, and it is time it was contemplated and acted upon.

One misfortune has been in electric lighting that a large investment has been available for only a small portion of the time. All day long, when other works by rental or by active employment were earning money, electric-light plants have been compelled to stand idle. Even gas companies spent the whole day making gas, accumulating it in their reservoirs for distribution during the night. Electric-light plants, however, are compelled to manufacture and distribute at one and the same time. A change, however, impends in which these costly plants and lines of copper can be used every hour in the twenty-four. The development of the facility for the transmission of electricity for power has, however, within the last two years, made rapid progress. The introduction into small manufactories of the current to be used constantly or intermittently has, in many localities, become very general. Already in the correspondence sent to me there are quite a few indications illustrating how advantageously the electric-light plants can be used during the day for the purpose of power. In cities where manufacturing is going forward there are hundreds of establishments in which the power required can be furnished from a central station. In the working of sewing machines, both in large establishments and in private houses, in the running of small lathes, hoisting machinery, elevators, and even large trip-hammers, in the circulation of air in sick chambers, in even rocking the cradle, the usefulness of electricity is becoming apparent, so that a new era opens for the usefulness of the plant, poles, wire, and franchises during the day.

In this respect, with this in view, the whole electrical community are watching with intense interest the possibility of the development in this city of Buffalo electrical transmission arising out of the successful effort which is now being made to harness the power hitherto latent in the Niagara river. The boldness of the proposal, the extent and character of the enterprise which is now nearing completion in this effort, the pluck and push in the work, challenge alike the attention of the engineering and commercial world. The relation of this enormous power of nature to the transmission of electricity is the most important consideration which now occupies the thoughts of those most interested. The success which has attended the three-phrase current from Lauffen to Frankfort in the transmission of power 112 miles, without material loss, comes just at the right moment to make it seem possible that the enormous potentialities in the forces of Niagara can be made to reach a degree of usefulness never dreamt of in the past and hardly realized in the wonderful present. It seems fortunate, therefore, that the convention which is here assembled should, as it were, be in the presence of the most stupendous event possible in the history of the science of electricity. In the development of the next few years will be found ample food for thought and effort, out of which may grow a relief for electric-lighting plants of the greatest possible consequence. If in the city of Buffalo and from the Niagara river there can be transmitted power in such enormous proportions as are now contemplated, subdivided and reduced, so that into every factory and almost into every house the force and energy can be controlled and operated, there is latent in every central station the possibilities that may come to every town in the country and to all the electric-light plants now lying idle during the day, an imitation in modified form of the power that of all forces in the world Niagara is the best example.

The success which has in so brief a period attended the application of electricity to traction, and the enormous numbers now moved throughout the country by electrical roads, make it reasonably sure that before very long steam roads in crowded localities will be worked by electric energy. Already the great Illinois Central, having so large a portion of its tracks in the city of Chicago, have in contemplation this marked change. The Wisconsin Central are also favorably considering it. Possibly it is a little too soon to anticipate this change, but that it is coming there can be no question.

In New York city, in Boston, in

Brooklyn, and in such suburbs as Staten Island, there is no reason why electricity should not be substituted for steam. Steam locomotives, built to carry their coal about and to employ an engineer and fireman for each 500 horse-power generated, cannot compete with the great compound, condensing stationary engine, whose forceful power can be extended by a delicate wire distances of 25 miles and under.

It is only a question of time when numerous roads, having a limited or circumscribed area, will consider the propriety of changing from steam to electricity, and, with that in view, electric-lighting plants now being constructed should contemplate a sufficient enlargement so as to be able to sell power to near-by steam roads. It would indeed be a revolution of enormous proportions if, from these central stations, a force sufficient could be furnished for operating suburban roads, whether steam or electrical.

In this connection it is impossible to contemplate the extension of the lighting and railway systems dependent on electricity without alluding to the consolidation now in progress between the two great electrical manufacturing organizations that, more than all others, have promoted these most important interests. After a somewhat careful study of the question of competition, of consolidation, and the establishment of a strong and well-managed single concern, as compared with weak and numerous rival undertakings, my deliberate conviction is that all the dangers of monopoly, all the possibly increased charges for supplies, and other fancied ills, are as nothing compared with the waste of unbridled competition. In the consolidation of the Edison and Thomson-Houston companies a new and important era opens for all interests concerned in electricity. With such experience, such skill, such business sagacity, and such inventive faculty as has been developed within these companies, now that they are united in one, nothing but good can result, not only to the companies themselves, but to the electrical community at large.

In the telegraph business a larger capitalization exists, in proportion to the cost of the material, with a capacity to earn a dividend upon the amount, than in any other department, while in the telephone, and more recently in the electrical railways, the amount realized is in excess of that from any other investment. It is true that in electric lighting a universal success has not been achieved, but beyond all question a great and useful purpose is being served in the creation of light, for which a profitable and steady demand exists and which can be supplied through the experience and the improvements attained as the result of the operations thus far.

The future is full of promise for these undertakings, especially in the value of the franchises, the ability to furnish power, in their combination with the gas industries of the country,—which must be only a question of time,—and in their ability to promote and to assist in the application of electricity to street-railway enterprises. The whole subject of electricity, as applied to business, is full of the deepest interest, and no one who feels grateful for having been born in this age and enjoying all the advantages of the most advanced civilization can fail to recognize in this wonderful force the advantageous contributions toward the good of mankind and hold in high estimation the men who in so short a period have so rapidly promoted its introduction and high degree of usefulness.

STEAM- AND PRESSURE-GAGES.

By A. B. Calkins, M.E.

AS is well known for many years, the instrument commonly known as the steam gage has occupied a prominent and important position in the field of devices for recording and showing pressures either above or below the atmosphere.

The better known of these devices are the Bourdon tube and diaphragm gage. The Bourdon gage consists of a flattened tube bent to conform to a circle, the length varying from one-half to four-fifths of the same, with a highly multiplied motion connecting the indexing-hand with the tube, so that the small motion generated by pressure in the tube shall be clearly and distinctly shown for every unit within its scope.

The diaphragm gage is formed by suspending a disc of any requisite thickness or diameter on its outer edge and clamping the same substantially between two concaved pieces, so that the disc may be allowed to move or buckle under the influence of pressure. A multiplied motion of practically the same order as applied to the Bourdon is applied to this.

The advent of the Bourdon gage upon the market and its introduction into general use was attended by no little opposition and distrust by owners of pressure receptacles. It is believed that the first application of the Bourdon system in this country was through Mr. E. H. Ashcroft, of Lynn, Mass., who while sojourning in England purchased the right to manufacture the article here from Mr. Bourdon, the inventor.

Mr. Ashcroft's experiences in trying to induce parties to try his device were of a discouraging character at first, but with persistence and energy he at last succeeded in getting permission to equip a locomotive with the trial gage.

I think the first operations by him were in 1851 upon a locomotive running out of Boston.

A good deal of skirmishing on his part was done in order to convince the railroad people that he would do no harm or in any way damage their machinery, their idea being that a clock-shaped thing was a poor and unreliable device for showing pressures. However, it came to be known first by one engineer and then another that an engine had the new device on, and as that particular engine passed others on sidings or was passed, all hands craned their necks to get a glimpse of the pressure-clock.

A few weeks only was necessary for the engineer to use the gage to admit as much liking and reliance as he had distrust formerly.

The compactness, neatness, and accuracy of repeated action and the convenience of noting the hand against the actual figure on a perfectly legible background took root in the minds of all seeing the device and thenceforward a steady growth toward an enormous business was the result.

The present demands for such devices are between 10,000 and 15,000 per month, with a steady increase in the trade. Unquestionably no means of a mechanical nature in a commercial sense could excel the Bourdon tube as a medium for showing pressures in sealed receptacles.

The features of its construction offer just such conditions that the fluctuations of pressure either up or down are acutely responded to and with as much certainty and precision as the pulsations in a thing of life.

These effects bear directly upon the first principles of the system and are undoubtedly what appeared to the inventor when first the idea was formu-

lated. No allowance could be made by him at this period for many defects that have appeared from time to time both in the character of the readings during operation and manipulations during manufacture.

The accompanying drawings show the Bourdon tube with its connections and general characteristics.

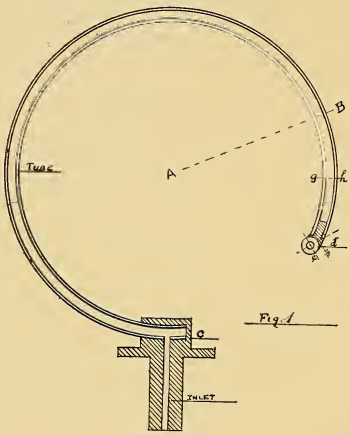


FIG. 1.

Fig. 1 is the tube alone with no recording-gear attached.

Fig. 2 is a cross-section of the tube through *A*, *B*, or any section in its length cut radially to its axis.

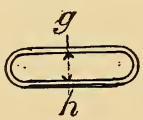


FIG. 2.

From this construction it is seen that the tube is flattened or oval through its cross-section, and its length is bent to occupy that portion of a circle best adapted by the thickness of its walls to the pressure to be sustained and shown.

The attachment or mounting at *c* is provided to make connection with the receptacle that pressure is to be shown in. The tip at *d* is so situated that it acts as a stopper for preventing the escape of pressure, thus effectually sealing it, and at the same time a point from which mechanism is suspended consisting of the recording or indexing-gear and hand.

It is apparent that pressure in the receptacle is simultaneous in the tube, and being so from a mechanical action that transpires during fluctuations of the pressures in the tube, the tip *d* is caused to move in the arc *e*, *f*. This action is brought about principally by the distension of the tube under pressure at its narrowest cross-section, or at *g*, *h*, Fig. 2.

The pressure forcing the inner curve toward the center and the outer curve outward creates a tendency to straighten out, giving by this action the motion as shown through arc *e*, *f*. The reverse of these operations by the tube is apparent in the same under the influence of a vacuum ; the air being displaced from within the exterior pressure of the atmosphere tends to collapse the tube, and thus the tendency to create smaller circles and provide the means of showing pressures below the atmosphere. This, as remarked before, shows the first principles as evolved by the inventor Bourdon, and so far as improvements go it practically is impossible to improve on. The case is one where one idea covers the whole field.

However, numerous modifications of the original Bourdon-Ashcroft gage have been and are being invented and put upon the market, the improvements and modifications being mainly in the mechanism that multiplies the motion leading from the tube tip to the indexing-hand. The incentive for this line of inventions is to overcome wear and lost motion, vibrations, and unequal timing of the hand with even spaces on the dial, equal pressure being sustained for equal position of the hand.

It is known by manufacturers to be a fact that the action of the tube during pressure fluctuations does not move directly proportional to the pressure ; that is to say, the distance moved through for 10 pounds is not exactly duplicated by an additional 10 pounds, but a falling off in the distance for each duplicate advance up to the extreme maximum limit of the tube. If it were possible to so arrange the action

of the tube under pressure that equal distances for equal pressures could be attained, the apparatus would be well-nigh perfect.

The dials could be printed by semi-automatic machines and the intermediate multiplying-gear be straightforward allusion to them will be necessary. To show the chances of improvement and point out a few facts pertaining to features made apparent to manufacturers during process of construction, along with a systematic routine of examination for purposes leading to more

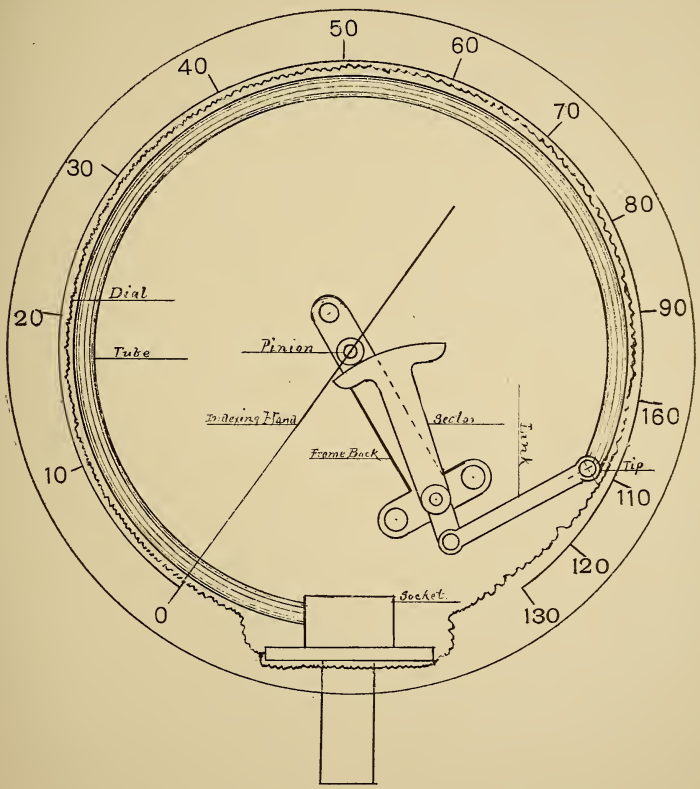


FIG. 3.

rack- and pinion-work to produce in an equal ratio the movement of the hand. As, however, this is not the case to insure accuracy, each and every gage dial must be individually marked with all mechanism in attachment.

As these parts are familiar to the general user of steam appliances, no accurate and reliable instruments, is the object of this writing.

It is customary to bend the tube around forming-rolls or push them through a die adjusted to give the requisite curvature. Previous to this, if bent around rolls, the tube is filled with sand to prevent buckling. A little con-

sideration will make clear the fact that, by bending, the tube becomes radically disturbed in its particles, the atoms of construction tending to come closer together on the inside, while on the outer side they are drawn further apart.

The tendency of this displacement is to create a set different from its normal condition and which reverts to serious detriment to the truth and accuracy of the gage. To obviate this difficulty it will be necessary to restore the particles to their normal conditions before proceeding to put the parts together for the last time. The accomplishment of this duty is through the medium of heat and vibrations,—heat to generate a higher state of motion, and vibrations or knocks to jar the particles into the state of equilibrium. Once this operation is gone through, the tube will remain in a positive condition, and the effects that are noticed in finished work sometimes showing the hand to have changed its position after test will be wholly eradicated.

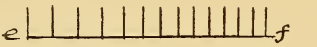


FIG. 4.—LINE *e*, *f*, MAGNIFIED 10 TIMES.

The movement or multiplying-gear gives no trouble on this score, but a defect is made apparent from the difference of readings going up under pressure to those coming down. This difference is not due to the inability of the tube to respond, but to lost motion in the movement, a matter that cannot well be eradicated as they are at present constructed. Also a very noticeable and serious defect in gages as now made is the short-lived rack or sector and pinion, the continued vibratory motion of the tube under pressure-fluctuations creating a wear on these parts that in very short time makes lost motion so apparent that repairs are necessary.

The performances of the gages on locomotives, farm and fire engines, and apparatus of like character are more susceptible to wear and tear than all others, owing to the jarring and jolting during their use.

Devices have been invented by several manufacturers in this country and Europe to obviate this wear and tear, but it still goes on, and always will as at present constructed.

The idea that should be looked forward to in the creation of a gage is that it should be so nicely balanced and susceptible of adjustment that the wear will be taken up automatically and its life made in consequence as long as the material stands from which it is constructed.

A perfect pressure-gage for commercial purposes will therefore be one constructed on practically the same groundwork as now being made by the several manufacturers, but modified to the extent that the defects of molecular displacement are corrected at the time of first stages of construction and automatic means to take up wear and bring the motion of the hand to time with equal spaces on the dial against the unequal movements of the tube.

It is quite possible that such a gage can be produced. If so, the system of pressure-recording apparatus and pressure relief apparatus can be made to work in exact harmony with each other.

It would seem to the users of pressure by casual observation regarding the apparatus for showing the same that it is well enough to abide by the rules and directions laid down by the manufacturers and not try to formulate any opinions upon the subject. So far as making adjustments or repairs the rules and directions should be followed implicitly.

But so far as his understanding the principles upon which the gage is founded, these he should have thoroughly impressed upon his mind, and with all details of construction fully shown.

The pressure-gage is an important article, bearing directly upon the safety of life and property; it is the only visible means of understanding the amount of energy confined, and in consequence everything in connection therewith should be mechanically correct and easy of comprehension, all methods of test made clear, and an understanding of the principles of the test factor. As generally known, pressure-gages are tested and given a rating on the mercurial column-testing stand.

All the features of the performance of the gage tested are shown during its comparisons with the different heights of mercury. A column of mercury 2.03601 inches high is equivalent to one pound on the square inch, and any pressure above is as many times that factor, and any pressures below the atmosphere an equivalent height of mercury under the influence of a vacuum produced by an air-pump.

The action of mercury being directly proportional in its heights against accumulating pressures, it is easy to see that any inequalities in the performance of the gage-hand can be readily noted. It is through the medium of the mercury column that the divisions on arc *e*, *f*, Fig. 4, are shown, and it is also through the same medium that test-gages are made.

While the mercury column is invariably at a constant temperature, test-gages may be in error from the effects of molecular displacement, as shown during the bending of the tube, making their product or new gages marked therefrom just as much in error.

To bring therefore the system of gages for showing pressures in harmony with the relief-valves or safety-valves, it necessitates the use of the mercurial column entirely for test purposes, and the erection of such at intervals of every city not further apart than 500 miles should be the rule, the city weight and sealer having charge of the same in his department. This system of columns then should be under the guidance and direction of one master column at the bureau of engineering at Washing, and subject to its certificate for accuracy rendered every quarter year, the *modus operandi* of the system of comparison being to furnish from the bureau of engineering at Washington a strip of metallic paper graduated into 300 divisions, that number being the limit of the columns in pounds on the square inch in its maximum amount.

By a mechanism that is already devised this strip of paper is made to move under the influence of the different and equivalent heights of mercury. Now, if the pressures of the column check off with the marks on the paper which have been rated on the master column, it can and will be considered correct. After the column has been tested by this comparative method, the paper is returned to the bureau of engineering and placed on file for examination, all differences noted, and if the column is found at variance with the master column, corrections are then in order. To keep the column in test during the interval between certifications a test-paper is furnished every column, which can be used in cases of question of error.

By the establishment of such a system any variance in pressure-recording showing on relief apparatus would be an impossibility, and errors in such apparatus could be traced and laid to its proper source and corrections speedily follow. The first cost of such a system would be the entire expense, as the officials now at hand could easily handle the extra apparatus without additional expense. The benefits derived would be the extreme satisfaction of knowing the quantities being handled and the qualities of the apparatus handling them, and these effects would hold good throughout the whole country. A standard of comparison would be realized.

Boiler inspectors and inspectors of every appointment on steam apparatus could and would be equipped with apparatus to qualify a test and so have an exact rating. The results of all tests would be alike, all steam-gages would be alike, and all safety-valves would flow in exact time with the steam-gage, also all relief-valves would be in harmony ; any doubts could be quickly settled on account of near-by apparatus for testing. The routine being once established, the system would be easy of attention and a time would be looked forward to when testing and overhauling of apparatus would be in order. As matters stand at the present time, under the methods pursued, it is fair to state that no plant equipped with a number of gages will find them all true to one another. Improvement is in order on this form of apparatus and undoubtedly something will be shown to the advantage of the public in the near future, bringing out more fully the advantages of the Bourdon system for showing pressures in sealed receptacles.

JOHN E. SWEET.

By F. A. Halsey.

JOHN E. SWEET was born in 1832, at Pompey, Onondaga county, N. Y. His father was a farmer by occupation and inheritance, his mother from a family of universal mechanics,—the Averys. The boy's education was limited to that obtainable between the ages of seven and fifteen at the local schools. His taste for books is said to have been limited, but his aptitude for mechanics came promptly to the fore. He can recall his early efforts with a keyhole saw while still in dresses, and his father's prediction, "That boy will make a mechanic." When twelve years old he made a small violin, and his people, fancying he had made the instrument because he wanted to learn to play it, placed him with a distant relative to take lessons. In the two weeks of instruction, which he still remembers as being a very long time, he came home able to play a half-dozen tunes. This one thing placed him ahead of his associates and made him a leader,—a position which, once obtained by a boy, is likely to abide by him as a man.

In 1850 he was apprenticed to the carpenter and joiner trade, fortunately with a man of ability and noble heart,—John Pinkerton, now of Saginaw, Mich., —who faithfullycarried out his obligation to teach the boy "the art and mystery of his craft." Among the tools bought with his first earnings was the second set of socket joiner chisels ever made, one of which is still kept by him as a memento. In the winter of 1850–51 he obtained, through the efforts of a former neighbor, a position in the first, and at that time the only, architect's office in Syracuse,—that of Elijah T. Hayden, fortunately, again, a man of noble nature. Here building fires and sweeping the office floor alternated with opportunities to see drawings made and to assist in such capacities as untrained fingers were capable of. Here, in paying his board from his own earnings, not for an education, but for an opportunity, he has often said, lay the best investment he ever made. For ten years his life was devoted to carpenter and joiner work, building, and what was then called architecture, but what was, in fact, the making of construction drawings for buildings. His designs or plans all bear the stamp of original arrangement and correct construction.

A second winter as office boy with C. O. Holyoke, a natural artist and a believer in Ruskin, directed the boy's thoughts to the channel of sound construction and the principle of suiting the construction to the use. He was here convinced that, however much he might admire art and wish to be an artist, if Nature had given him any faculty worth cultivating, it was in the direction of mechanics and not art. Building at that time and within his field of operation was mechanical and not artistic. In the middle '60's he built unquestionably the most unique and best farm barn in the country. The plans for this barn received the first premium in a national competition held by the then leading agricultural paper in the country,—the *Rural New Yorker*. They were repeatedly published in that paper and were followed by a series of articles, from his pen, on architecture, extending through a dozen years.

The breaking out of the war found him in Selma, Ala., as architect and superintendent of what was intended to have been the second best hotel in the South. Discretion induced him to leave one rainy day, and the work on the hotel soon ceased. His services as architect being in little demand during those troublous times, he spent some time as pattern-maker and draughtsman in the railroad shops of Syracuse. In the summer of 1862 he went to the London Exhibition, spending some months on the Continent and the remainder of the year as a draughtsman in the international patent office of Hazeltine, Lake & Co. An account of his travels was given in a series of twenty letters to the Syracuse *Standard*. Thirty years ago letters on foreign travel were less com-

mon than now and were read with much interest. With characteristic modesty he attributed his best remarks to a fictitious traveling companion, fearing his readers would not think him capable of making them. Securing a patent on a nail machine in which the Patent Nut and Bolt Company, of Birmingham, England, took an interest, he went there and worked for them as draughtsman while superintending the construction of the machines. While there some short articles were furnished to Zerah Colburn and published in *Engineering*.

As a piece of ingenuity and perfection of devices to accomplish its end, it is doubtful if anything more perfect has been produced, though more successful work may have been done. The material used in this machine for the matrix—paper pulp—is still adhered to. The machine was exhibited at the Paris Exposition in 1867 and was later given to Cornell University, where it is now. Returning to Syracuse from the exposition, he again connected himself with Sweet, Barnes & Co. and for three years had charge of their works. In November,

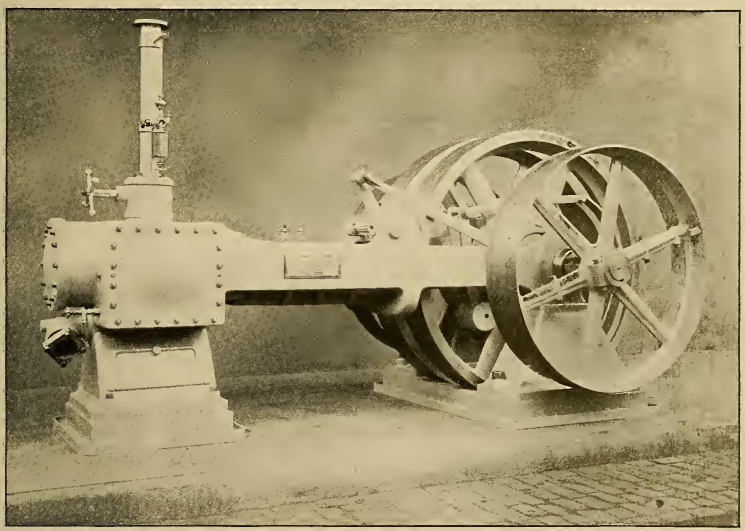
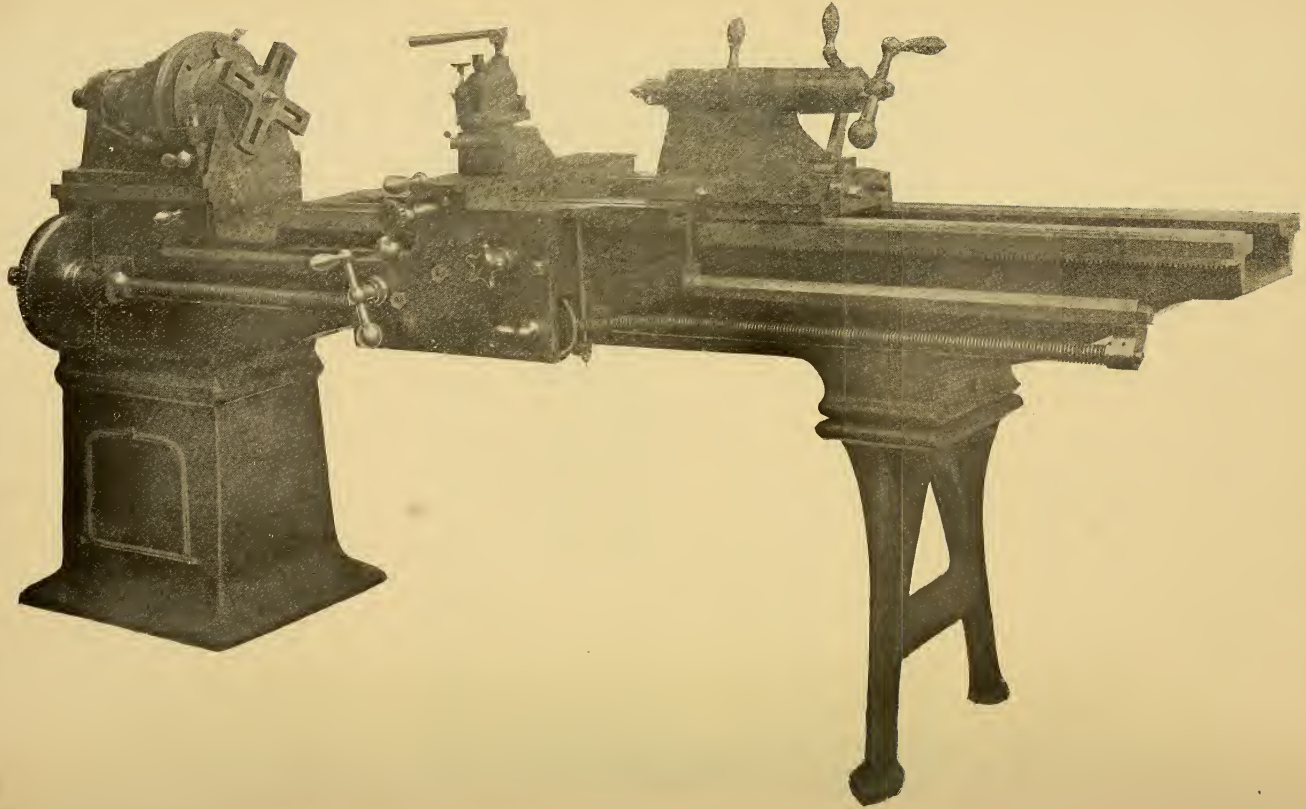


FIG. 1.—STRAIGHT-LINE ENGINE DESIGNED BY PROFESSOR JOHN E. SWEET. BUILT BY STEINLEN ET CIE., OF MULHOUSE, ALSACE.

Returning to Syracuse in 1864, he engaged with Sweet, Barnes & Co. as designer and draughtsman. He here designed a large number of machines, tools, and appliances, introducing some of the features that still mark his designs. During these years he designed and had built one of the pioneer machines aiming to supersede the use of movable type, from which the linotype is a step in advance. This was to have been done through the formation of a continuous matrix by means of steel types or dies.

1870, he was married to Caroline V. Hawthorne, an accomplished lady, with whom he lived in perfect harmony until her death in 1887.

From 1871 to 1873 he was mainly occupied in bridge-building for Howard Soule, and during leisure in the fall and winter of '72 made the plans and patterns and did most of the work on the first straight-line steam-engine. Also during this time he contributed twenty articles to *Engineering* under the title "Mechanical Refinements," and over the sig-



ENGINE LATHE DESIGNED BY PROFESSOR JOHN E. SWEET. BUILT BY THE UNIVERSITY OF WISCONSIN, MADISON, WIS.

nature "An English Engineer in America," both title and signature being selected by the editors.

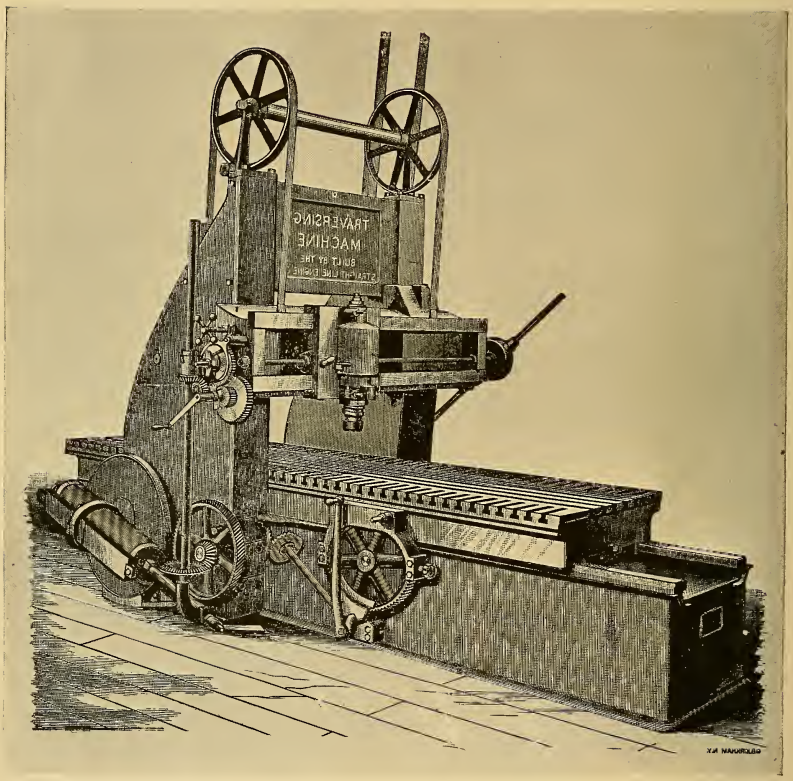
From 1873 to 1879 was the period of connection with Cornell University, the title of professor not being conferred, however, until '78. The mechanical work done here was of a pioneer character. While the W. Whitworth surface plates and straight edges were known to a few in this country, their manufacture and introduction to the public date from the Cornell shop. The first standard measuring machine made in this country was made and is now stored there. This machine may almost be called a mechanical classic. It is, in the writer's opinion, superior to any that have followed it, and no less an authority than John Richards has testified that its method of correcting the error of the screw is the only one known that is commercially practicable.

The equally important problem of neutralizing the effect of wear was solved in an equally successful way, though one that has not yet been adopted to the same extent. This measuring machine was to have been the foundation of a system of standard gages whose manufacture the professor hoped to establish in connection with the college shop. This, again, was pioneer work, nothing of the sort being commenced elsewhere until some years later. Other principles which have since come into use—some universally and others partially—were embodied in some amateur lathes and a grinding machine. The first gramme dynamo produced in this country was built here, and the second straight-line engine. These, with other products of the shop, were exibited at the Centennial Exhibition. This straight-line engine embodied what was then the novel combination,—a balanced valve, a shifting eccentric, and a shaft governor. This has become the accepted type of high-speed engine, and this Centennial engine is fairly entitled to be considered the father of that numerous family. It should be added that all this work was produced by student labor, no other being employed in the shop.

The professor's chief work, however, at Cornell was not the fashioning of iron, but the molding of brains. The Sibley College of that day was the insignificant tail of a not very significant dog. As a college department it was felt to be an anomaly by the powers that were. The professors, bred in the scholastic atmosphere of languages, mathematics, or pure science, gave it little sympathy and less support. This feeling was no doubt strengthened by the fact that the "theoretical" side of the department, with which they might have had some sympathy, was, in fact, at a low ebb. In equipment, apparatus, etc., the department was, compared with itself of to-day, a kindergarten, and of its merits as a school the same comparison would hold. True education, however, consists of the training of the faculties and the formation of correct methods of thought and work rather than the accumulation of information, and these it is the province of the true teacher to impart, largely independent of material aids and resources. Those who came as students under Professor Sweet's influence feel that in this respect they enjoyed a priceless privilege. As a teacher he was one of those —few and rare—whose pupils become disciples.

Seeing no prospect of co-operation or support in doing what he felt to be possible, and what has since been done, he resigned his position and returned to Syracuse. Experimenting with the original engine and obtaining what appeared to be the maximum of simplicity and perfection of action in the governor, he commenced building the engine in a very modest way. The Straight-Line Engine Company was soon organized, with him as president and general manager, which position he still holds. In the organization of the American Society of Mechanical Engineers he was one of the prime movers. He was elected one of its managers and, after repeatedly declining the honor, was elected its third president. In 1889 he married Irene A. Clark, of Syracuse, who aids him in his work and shares every gleam of sunshine and shadow.

Among the many machines designed and invented by Professor Sweet is the straight-line engine. An illustration of this type of engine as built by Steinlen et Cie., Mulhouse, Alsace, is shown on the preceding page.



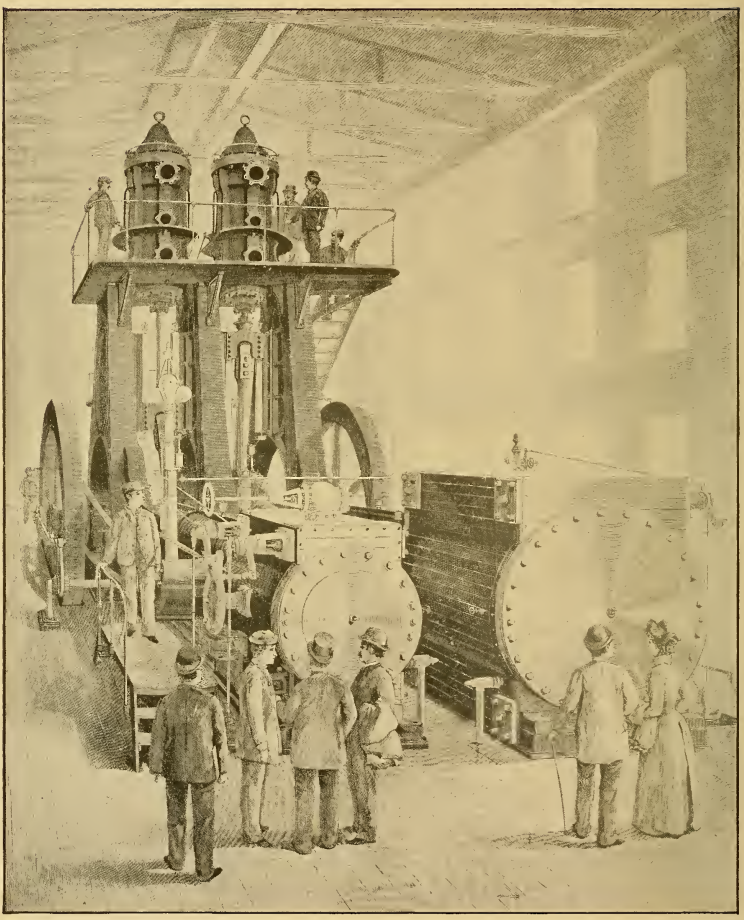
TRAVERSING MACHINE, WHICH DOES SURFACING, MILLING, BORING, AND DRILLING WITHOUT CHANGE IN TOOL. DESIGNED BY PROFESSOR SWEET.

Fig. 2 shows an engine lathe built by the Mechanic Arts Department of the University of Wisconsin, at Madison, and Fig. 3 a traversing machine built by the Straight-Line Engine Company, Syracuse, N. Y., which does surfacing, milling, boring, and drilling without any change in tool and with which steam-tight joints are made without hand-work or packing, all of Professor Sweet's design.

Professor Sweet has never aspired to doing a large business. He has preferred to "live upon a small rocky island of his own, with a lake and a stream in it, pure and good," to uphold ideals of his own, often far in advance of commercial appreciation. He has never undertaken any task for the money that might be made from it, but rather to accomplish the mechanical feat, and of the hundreds of patentable inventions he has made, patent protection has been asked for but very few. In design he is unique,—novelty everywhere, though much more than mere novelty. As a well-known engineer recently remarked on examining the straight-line engine for the first time, "I would not have believed it possible to introduce so many novelties and have all of them good." The influence of his early artistic studies is apparent in every line, not manifested in superfluous ornament, but in that higher and in engineering structures only true beauty,—the beauty of perfect fitness. The writer once heard a remark passed on the lines of a machine made up partly from patterns of some older work of the professor's and partly from new designs by others, to the effect that "it was easy to tell where the master's hand left off and the cobbler's began in that machine."

He has seen too much of the world and of the work of other peoples and has too cosmopolitan a judgment to feel any sympathy with that spread-eagleism which vaunts our own work in ignorance of others. More than this, he believes it to be in as bad taste for a nation to boast as for an individual to do so. He considers it a misfortune that our mechanics should slight instead of study the works of the Old World.

With no desire for popularity, yet exceedingly popular; of unswerving faithfulness to the highest mechanical ideals, yet successful in business; with no gift of eloquence, yet always holding his audience; modest to a fault, yet with his merit universally recognized, Professor Sweet is a reassurance to those who sometimes feel driven to the conclusion that after all brass is better than brains and that in this world modest merit is the one thing that escapes its just reward.



500-TON REFRIGERATING MACHINE BUILT FOR THE ANHAUSER-BUSCH BREWING COMPANY, ST. LOUIS, MO. CONSTRUCTED BY THE DE LA VERGNE REFRIGERATING MACHINE COMPANY, NEW YORK.

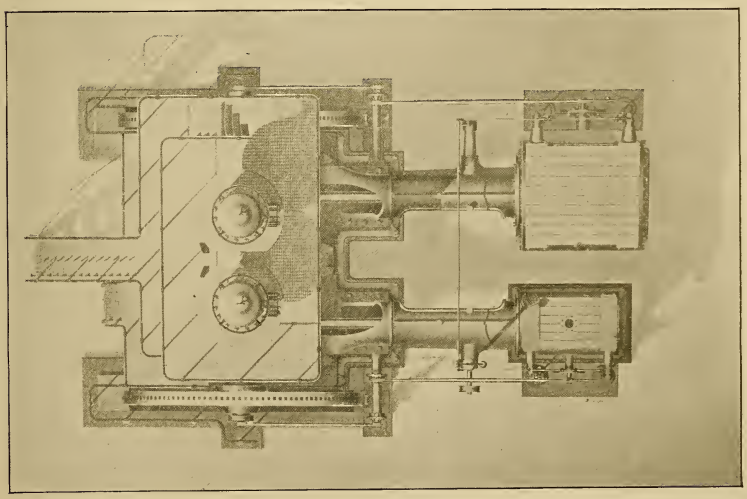
A LARGE REFRIGERATING MACHINE.

ON the following pages are shown illustrations made from drawings of a refrigerating machine recently constructed for the Anhauser-Busch Brewing Company of St. Louis, Mo., by the De La Vergne Refrigerating Machine Company of New York, and shows the largest ice-making or refrigerating machine in the world.

The capacity of this machine for refrigerating, when making forty revolutions per minute, is equal to the work of cooling accomplished by the melting of 500 tons of ice in twenty-four hours. The machine is 28 feet 6 inches high and occupies floor space 37 feet 4 inches by 22 feet 3 inches.

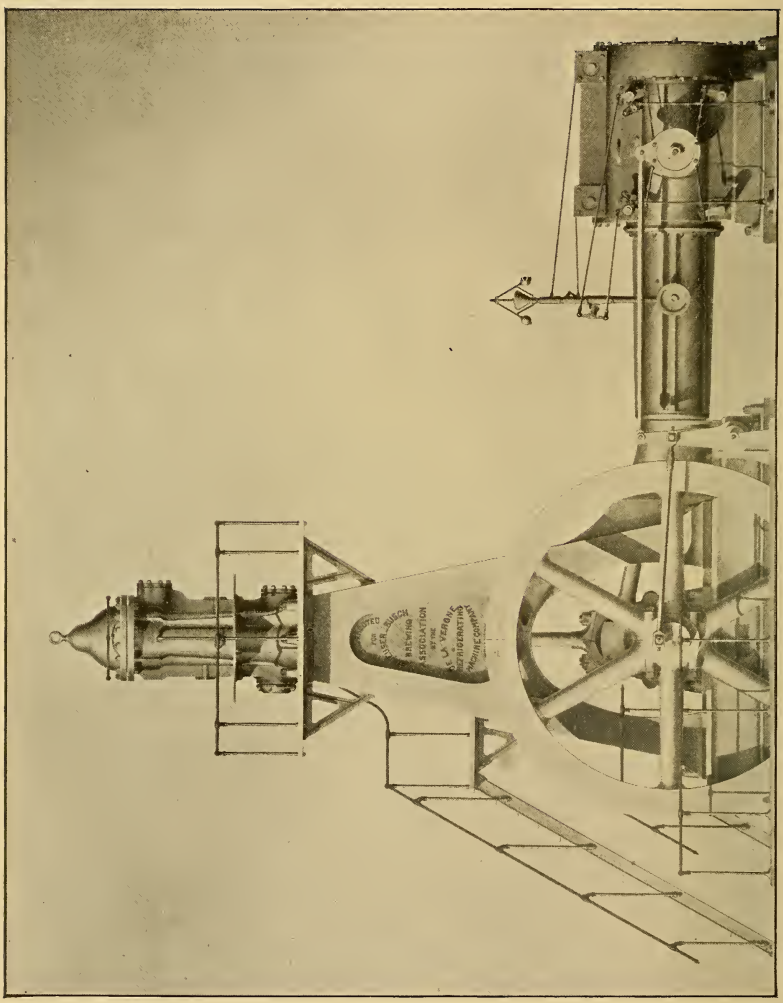
The total finished weight will approximate 175 tons. There are two fly-wheels the diameters of which are 14 feet 8 inches and weighing 28,000 pounds each. The crank-shaft is 15½ inches diameter, and is one solid forging with double-throw cranks at 157°; the cranks have each two wrought-iron bands shrunk on 2 inches thick, the crank-pins are also 15½ inches diameter, and each pin takes the end of a steam and compressor connecting-rod. There are two steam and two compressor-rods; the steam rods weigh 3800 pounds each, and the compressor rods 3400 pounds each; the boxes are made of phosphor-bronze.

The shaft-bearings and the compressor cross-head gibs are also made of phosphor-bronze; the total weight of bronze in the rough contained in the pieces named amounts to four and one-quarter tons. The 600 H.P. engine is of the Corliss type and is cross compound condensing; sizes of cylinders are 32 and 64 inches by 48-inch stroke, and are lagged with cast-iron which is polished and nickeled. The machine accomplishes its rated capacity when making forty revolutions per minute, with steam pressure at the boilers of 125 pounds.



PLAN VIEW OF 500-TON DE LA VERGNE REFRIGERATING MACHINE.

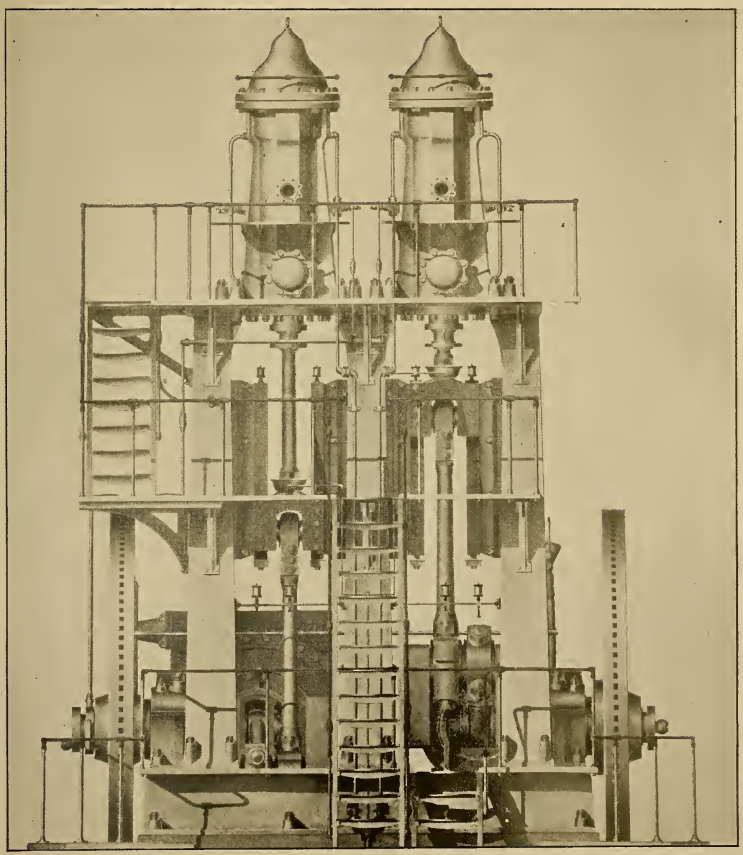
There is a cast-iron platform built on each side of the steam cylinders so that



SIDE ELEVATION OF 500-TON DE LA VERGNE REFRIGERATING MACHINE.

the engineer can very readily get at any part of the valve-gear or for manipulating the throttle. The weight of the low-pressure cylinder is 26,000 pounds, and the high-pressure 14,000 pounds.

The two ammonia gas compressing-cylinder being 15,000 pounds. They rest vertically on three A frames, each weighing 16,700 pounds. The upper discharge in each compressor is comprised of four steel valves, which are ground to their respective seats in one

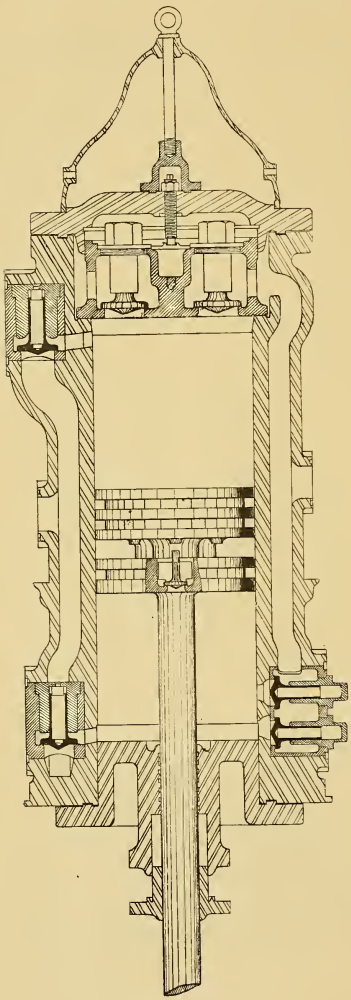


END ELEVATION OF 500-TON DE LA VERGNE REFRIGERATING MACHINE.

cylinders are 24-inch diameter and 48-inch stroke and are double-acting, made of charcoal gun-iron, and are tested to a hydrostatic pressure of 500 pounds per square inch, the weight of each large cast-steel housing $29\frac{3}{16}$ inches diameter and $11\frac{3}{4}$ inches high. This has also one seat which is ground in the compressor cylinder directly on the upper end of the bore, leaving only $\frac{1}{16}$

inch clearance between the piston and the upper discharge-valve housing.

The lower discharge is also comprised

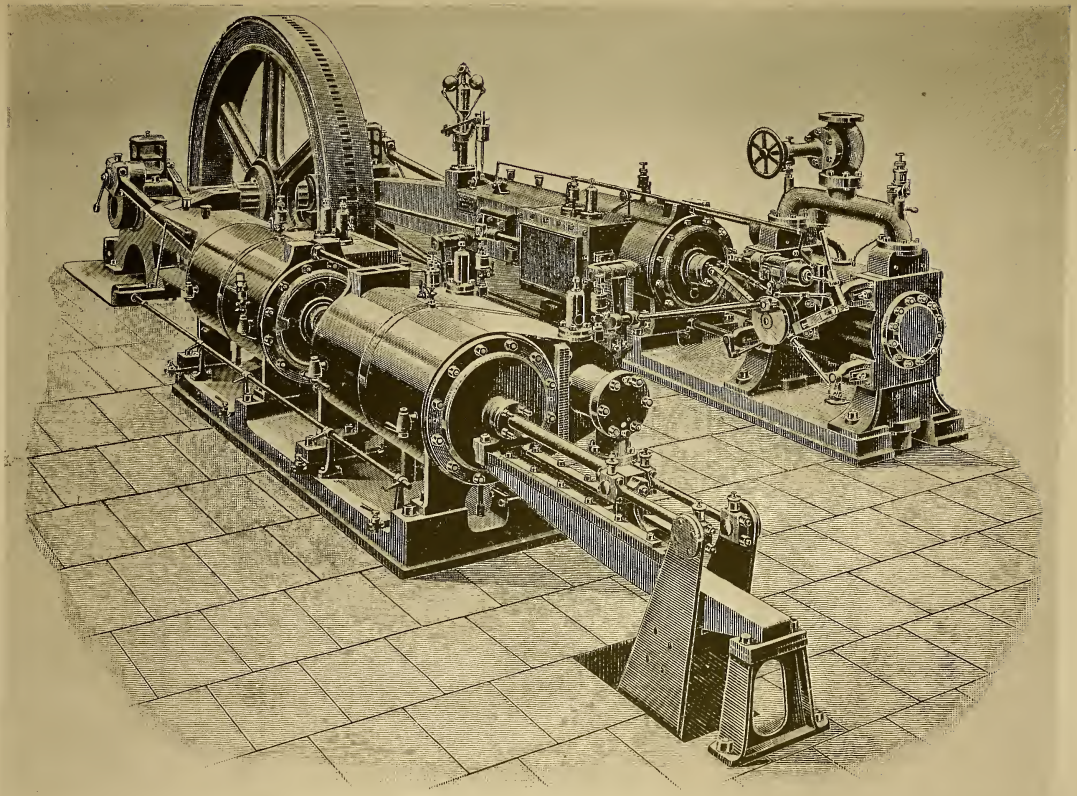


COMPRESSING CYLINDER.

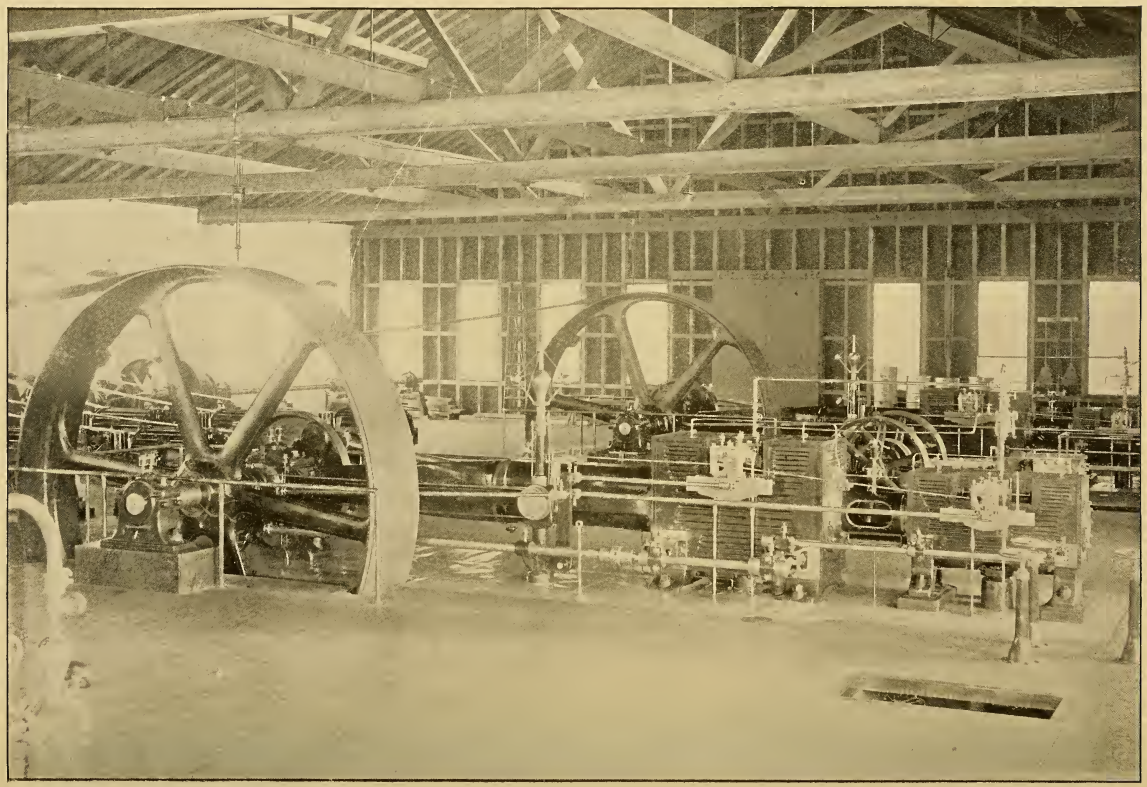
of four steel valves which are ground to their respective seats in one cast-steel housing, but are horizontal; while the upper discharge-valves are vertical, the lower discharge-valves are so arranged that when the piston comes down it covers two of the valves, leaving the two lower ones open to the discharge-pipe. In a further course of the piston, and as soon as the lower valves are closed, the upper ones are in communication with an annular chamber contained in the piston. This chamber has valves in its lower section which open into the chamber as soon as all other outlets from the lower side of the piston are closed, and now the gas will all go out through the piston, and after the gas the oil will follow, thus permitting no gas to remain for re-expansion on the lower side after the completion of the down-stroke.

There are two suction-valves to each compressor, one at each end of the cylinders; these valves are made of steel, and are ground in housings made of gun-iron; these housings are ground into pockets in the cylinder which receives them. The very excellent method of injecting cold oil in the compressing-cylinders at each end of the stroke, which is one of the peculiar features of the De La Vergne system, and used on all their machines, is governed by an eccentric on the low-pressure end of crank-shaft, arrangement being provided for injecting more or less oil at the will of the engineer. This oil not only serves the purpose of cooling the gas while being compressed but also thoroughly lubricates the piston, seals the valves and stuffing boxes, and obviates the necessity of recompressing gas by doing away with all clearance. There is a platform around the machine at the top of bed-plate, one just above the fly-wheels from which the engineer can get at the compressor cross-heads, etc., one at the base of compressing-cylinders, and one, as will be seen, around each compressor from which the bolts in the top head can be handled. The machine is well guarded and surrounded by bright polished brass hand-railing passing through polished sockets on the extremities of highly-finished iron stanchions.

The view of this machine on page 480 was made from an engraving in the *Scientific American*.



DOUBLE-TANDEM COMPOUND ENGINES CONSTRUCTED FOR A COTTON MILL BELONGING TO THE KAMPENHOFS AKTIEBOLAG, UDDEVALLA, SWEDEN, BY HICK, HARGREAVES & CO., SOHO IRON WORKS, BOLTON, ENG. (See page 456).



TANDEM COMPOUND GREENE ENGINES AT NEW HAVEN ELECTRIC-LIGHT COMPANY'S STATION, NEW HAVEN, CONN. CONSTRUCTED BY THE PROVIDENCE STEAM-ENGINE COMPANY, PROVIDENCE, R. I.

A NEW TANDEM COMPOUND ENGINE.

ON the page opposite is printed an illustration showing the plant of the New Haven Electric-Light Company at New Haven, Conn.

The plant consists of three tandem compound Greene engines, built by the Providence Steam Engine Company, of Providence, R. I. The high-pressure cylinders are 12 inches and the low-pressure 22 inches in diameter, stroke of each engine being 42 inches. The fly-wheels are 32-inch face, 14 feet in diameter, and weigh 14,000 pounds each. The engines have a normal capacity of 650 H.P., or about 217 H.P. each, running at 105 revolutions per minute. The dynamos are run from the main line of shafting, which is made up of three divisions, all of which may be coupled together by clutch-pulleys, or any one or two sections may be run with any of the three engines. One of the engines may run the whole line of shafting and any of the dynamos. This arrangement of shafting, in case of accident to any dynamo or any one of the engines, would enable the plant to continue in operation without any delay, for, although the normal capacity of each engine is but 217 H.P., as a matter of fact they are capable of supplying and at times supply as high as 300 H.P. each, and could if necessary develop 100 H.P. more each. The engines are also arranged so that if necessary the low-pressure cylinder could be run simple condensing or non-condensing, and under these latter conditions develop 400 H.P. each. These arrangements, as will be seen, are invaluable to a plant running under such trying conditions as is called for in an electric-light establishment.

The bed-plates are of the girder pattern and symmetrical in appearance; the main journal-boxes are made in four pieces, provided with set-screws and check-nuts, which permit of convenient and accurate adjustment. The governor is of the Porter pattern and is driven by a flat belt from the main shaft. The valve-gear is detachable and so controlled by the governor that the cutting off may be effected from zero to three-quarters of the entire stroke. The valves of each cylinder are four in number,—two steam and two exhaust,—and are of the flat-slide pattern. The power which moves them is applied parallel to and in line with their seats, so that they cannot rock or twist, thus obviating the tendency to wear unevenly. The steam-valves when tripped are shut by a combined action of a weight and the pressure of the steam on the large valve-stems, thereby ensuring a quick cut-off and the positive closing of the port under all circumstances of speed and pressure. The steam-valves are operated by toes on the inner ends of two rock-shafts that connect with the valve-stems outside the steam-chest. The outer ends of the rock-shafts are furnished with steel-tipped toes.

There is a sliding-bar carrying tappets, which receives a reciprocating rectilinear motion from an eccentric on the main shaft. Below the sliding-bar is a gage-plate connected with the governor which receives an up-and-down motion from a reverse action of the governor-balls.

The tappets in the sliding-bars are attached to the gage-plate and elevated or depressed in the bar by the action of the governor. As the sliding-bar moves in the direction of the arrow one of the tappets is brought in contact with the inner face of the toe on the rock-lever, causing it to turn on its axis, thereby opening the steam-valve at one end of the cylinder. At the same moment the other tappet comes in contact with the outer face of the other toe, and, as the surfaces are beveled, the toe is forced up into the socket until the tappet passes under, when it drops by gravity alone into its original position, to be operated upon in its turn when the motion of the sliding-bar is reversed.

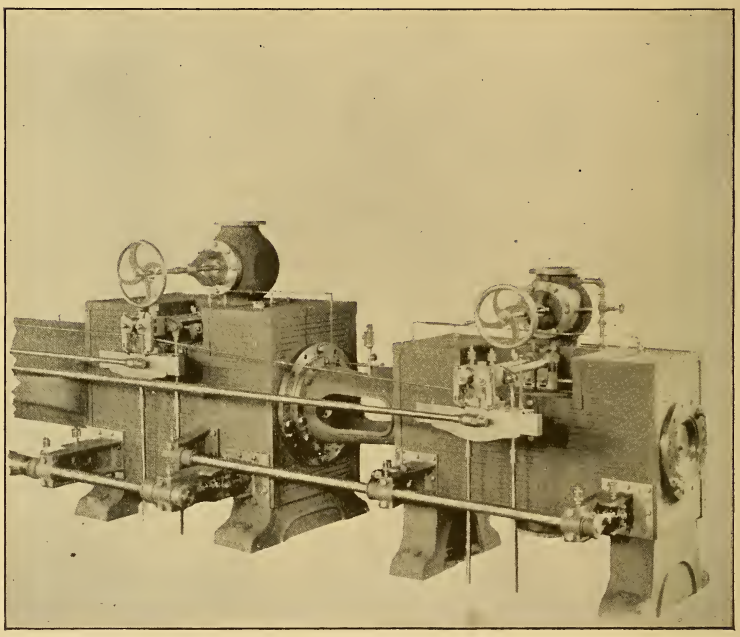
As a result of this motion, the tappets always give the valves the same lead, and as the bar moves in a straight line, while the toe describes the arc of a circle, the tappet will pass by and liberate the toe, which is brought back to its original position by a weight and the steam-

pressure on the large valve-stem, which thus closes the valve and cuts off the steam. The liberation of the toes will take place sooner or later, according to the elevation of the tappets ; that is, the lower the tappets are, the sooner the toes will be liberated and *vice versa*. By the elevation or depression of the gage-plate the period of closing the valves is changed, while the period of opening them remains the same. The adjustment of the gage-plate is effected directly by the governor.

Both the exhaust-valves and seats are convenient of access and removable from the outside of cylinder. The valves receive their motion from a separate eccentric, thus allowing of easy adjustment without interference with the steam-valve mechanism. All the connections are on the outside, are few in number, and have ample bearing-surfaces, ensuring freedom from rapid wear and derangement.

One valuable feature of this type of engine is, that any water which may enter the cylinder, whatever the quantity, is expelled through the same ports by which it may enter, thus avoiding the necessity of any auxiliary appliance.

A safety stop-motion is combined with the governor, preventing the admission of steam should the governor belt run off or break.



CYLINDERS SHOWING VALVE-GEAR OF IMPROVED GREENE ENGINE.

AA' are the two rock levers ; *BB'* the sockets attached to them and within which the toes *KK'* are contained ; *CC'* the arm of the levers attached to valve-stems ; *DD'* the valve-stems ; *EE'* the steam-chest ; *F* the governor-rod ; *GG'* the tappets ; *L* the gage-plate ; *H* the gage-plate guide ; and *J* the sliding-bar.

The sliding-bar *J* is shown moving in

the direction of the arrow, causing the tappet G' to operate upon the toe K', giving an opening movement to the valve-stem D', the tappet G meanwhile passing under and lifting the toe K. The amount of opening of steam-valves is determined by the height of the tappets GG', the positions of which are always under control of the governor. The toes drop by gravity, no springs being used, thus relieving the governor of all strain while tripping.

It was at the works of the Providence Steam Engine Company that John Babcock first began building steam machinery, and in 1830 completed his first engine. It was a beam engine, and after the general principle of Boulton & Watts. One of his engines was made for Jacob Dunnell, of Pawtucket, R. I., and he also built the first engine that was applied to the running of cotton machinery at Bristol, R. I.

Frederick E. Sickles patented his cut-off in 1842. This consisted in detaching the valve entirely from the mechanism that worked it, allowing it to drop automatically into its place. He brought his plans to this shop, and the first application of the principle was made here. Zechariah Allen, of Providence, R. I., who was a natural mechanic and had given great attention to the steam-engine, improved upon Sickles's device by attaching the governor to the mechanism, so that the cut-off would occur at any point of the stroke desired. This is the leading feature of the Corliss engine, which was patented by Mr. Corliss in 1849.

In 1855 Mr. Noble T. Greene patented his cut-off, which was also a liberating valve-gear, and the company built the engine under royalty until their construction was enjoined by George H. Corliss. At the expiration of the Corliss patent they occupied two years in the selection of an engine which was to furnish them with a business, and not finding any which met with their approval, they bought the Greene patent, and designed an engine which contains the valuable features of the Greene engine, but embodied in such form as to disarm criticism. This engine they have designated as the improved Greene engine, to distinguish it from the original Greene.

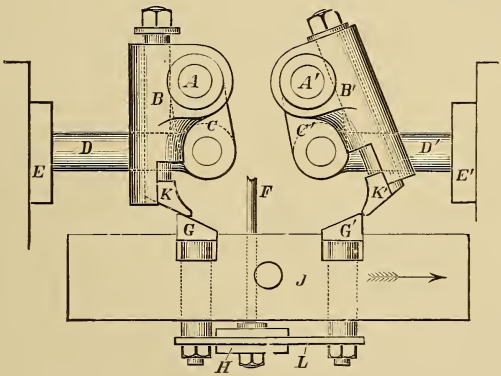
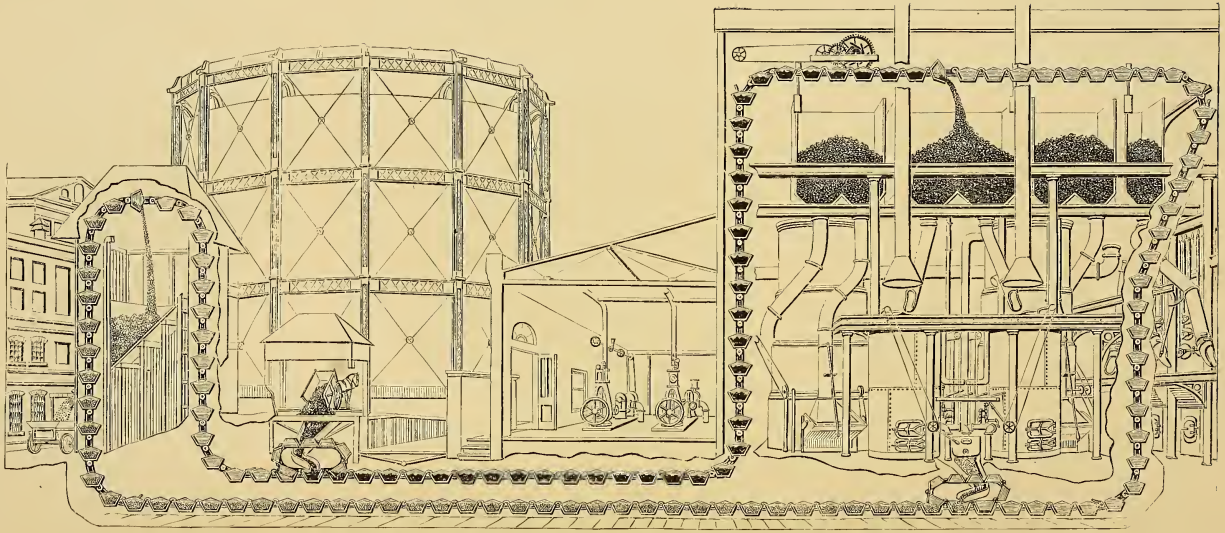
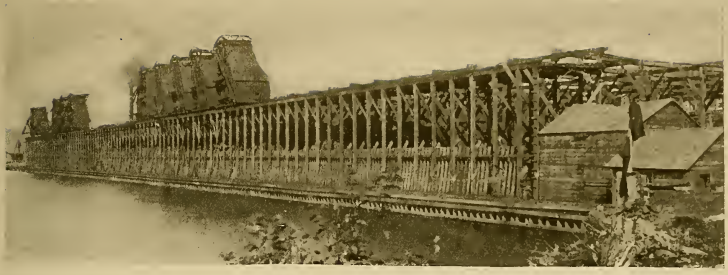


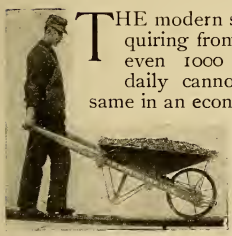
DIAGRAM SHOWING ACTION OF STEAM VALVE-GEAR.



CONVEYOR FOR COAL AND ASHES AT THE WORKS OF THE MILWAUKEE GAS LIGHT COMPANY, MILWAUKEE, WIS.
CONSTRUCTED BY THE C. W. HUNT COMPANY, NEW YORK.



MODERN COAL CONVEYORS.



THE modern steam plant requiring from 50 to 500 or even 1000 tons of coal daily cannot handle the same in an economical manner by hand. The steam-user in consulting his interests locates his plant near a railway or water way, where cars or vessels can come almost to his door and without any intermediate handling his coal is taken direct from the hold of the vessel or from the cars and conveyed to this power-house, which, if it is of modern origin, should have an automatic stoking arrangement dispensing with more than three-fourths of the help necessary to fire his boilers, saving waste and keeping boilers more even in coal consumption than can be accomplished by hand-firing.

Not alone for steam-power plants, but for loading or unloading vessels, moving coal so that it can be easily shipped to locomotives, stowing it in coal-yards, conveying the ashes and refuse away from buildings, and in many other ways, has the automatic conveyor been made one of the most useful and economical of modern inventions. The method most used is a system of buckets operated by an endless chain, or a way or chute along which the material to be handled is pushed by a chain, to which are fastened pieces of metal which are attached at fixed distances and take up a regular quantity of material as long as it is in motion.

On the opposite page is printed an illustration of the works of the Milwaukee Gaslight Company, which shows how the coal is brought from the store-house across the street and dumped into the conveyor and carried underneath the floors to the generator room and dumped into large hoppers over the generators. The buckets on the return carry the ashes out into the yard and dump them into a hopper to be drawn into a cart for removal. The conveyor is curved to suit the space that could be found in a previously constructed building. The engraving clearly illustrates the conveyor, which is arranged in a very similar way to those used at Spreckles's sugar refinery, in Philadelphia, where, in connection with the Roney stoker, the labor of coal-handling and firing has been reduced to a minimum.

The tendency of machinery for handling coal, iron ore, and similar materials has been toward more rapid work, and at a less expense per ton, necessarily requiring machinery that is heavier, more complex, and more expensive. The change from doing the work almost entirely by hand to the present method of doing the work wholly by machinery has been a gradual one. The first method required a great amount of hard physical labor. The present method requires but little exertion on the part of workmen, but requires more skill, entails

greater responsibility, and a higher rate of wages per day. It will give a clearer idea of the changes in the method of handling, to follow the gradual improvements that have been made.



UNLOADING VESSELS IN WEST INDIA PORTS.

The primititive method of unloading coal from vessels was for the workmen to carry it ashore in baskets on their heads. This method is still in general use in India, Africa, the West Indies, and South America. From 50 to 150 men and women work together, and take out from three to four tons per day to each person employed. The wages paid are only a few cents per day, and the laborers are at about the lowest point in the scale of civilization.



HANDLING COAL AT CINCINNATI, OHIO.



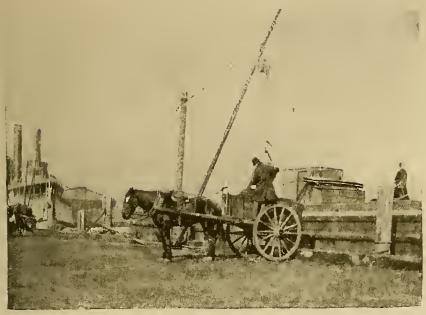
UNLOADING COAL AT NEW ORLEANS.

An improvement on this method is the one now in general use at New Orleans and other lower Mississippi ports. The coal is shoveled directly into the wheelbarrows and wheeled ashore on temporary plank runs. Eighteen wheelers, with a water-carrier and an axe-man, make a gang; there being two gangs to each boat, making a total of about forty men. Each man takes out on an average about six tons of coal per day.

At Cincinnati, Louisville, and St. Louis the coal is shoveled into cars instead of wheelbarrows, which is an improvement upon the lower Mississippi methods, but yet is very laborious and expensive.

Another improvement was made by erecting a mast and gaff, using half-barrels as tubs and hoisting the coal with a horse, and dumping it into a cart, or into wheelbarrows on an elevated run. This saved wheeling the coal uphill or throwing it a great distance into cars. With this method there were employed two shovelers, one man to lead the horse, and from four to six men for dumping and wheeling, making a total of seven to nine men employed. The daily output was about ten tons per day for each man employed. In 1857, Mr. George Focht, instead of the round wooden tub, devised a peculiarly shaped and balanced iron tub, which is now in almost universal use. This tub is top-heavy when filled, and bottom-heavy when empty; it is self-dumping and self-righting. It is also formed so that it is much easier to fill than a round tub. This did not reduce the number of men, but increased their efficiency, and made

the daily output about twelve tons for each man employed. An improvement



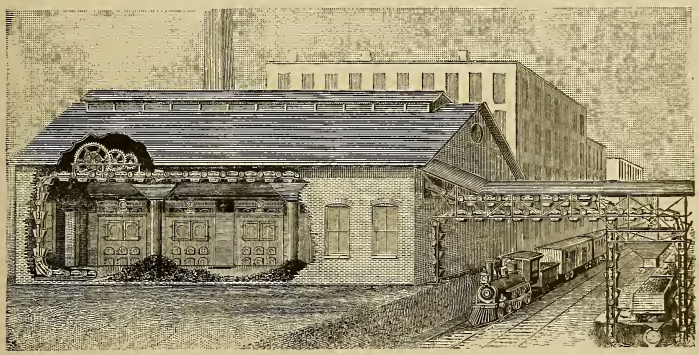
MAST AND GAFF FOR COAL-HOISTING IN NEW YORK.

made by Mr. P. K. Dederick, of Albany, N. Y., was a horse-hoisting machine that very materially reduced the labor of the horse in hoisting. Previous to this the horse walked forward to hoist a full bucket, and was obliged to back to lower the empty bucket into the hold of the vessel. With most horses this latter was harder work than hoisting the loaded bucket; while the Dederick machine increased the speed of unloading but little, it reduced the labor of the horse about one-half.

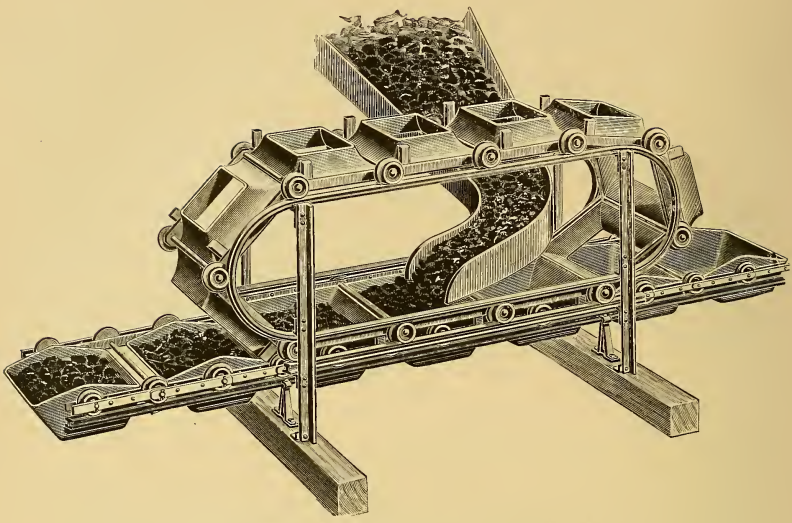
The use of a belt or chain with buckets attached for moving materials answers the purpose in many circumstances better than any other method. This conveyor, of which an illustration is shown on the next page, differs from the ordinary chain-conveyors used for this purpose in many particulars. While it is usually called a conveyor and classed with this machinery, it is, in fact, a series of cars linked together having a body hung on pivots, gravity keeping them in an upright position no matter how tortuous the track over which the cars may be drawn.

It will be seen that the buckets hang upright in all positions of the chain, consequently the chain can be run in any direction that may be necessary without affecting the buckets, as the load will be carried just as securely in one direction as in another.

The necessity for a special method of filling the buckets will be apparent when it is considered that they swing freely on pivots and might oscillate to a harmful extent or might be loaded on one side and remain at an angle during the trip. This is accomplished so perfectly that an observer watching the machine at work would not notice that there was any liability of swinging or uneven loading. Two methods of filling the buckets are used, one a "measuring filler," the other a "spout filler." The "measuring filler" delivers to each passing



CONVEYOR ARRANGED FOR LANDING COAL IN A BOILER ROOM.



THE HUNT CONVEYOR. MADE BY THE C. W. HUNT COMPANY, NEW YORK.

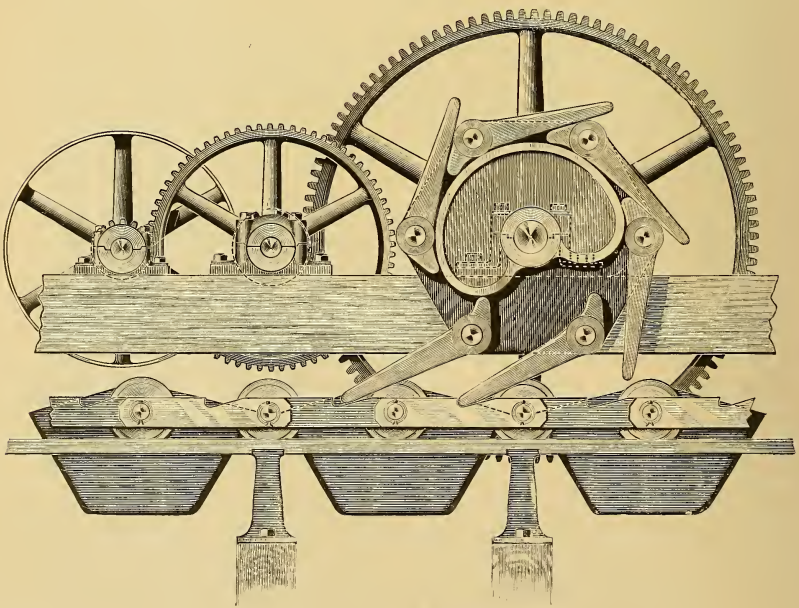


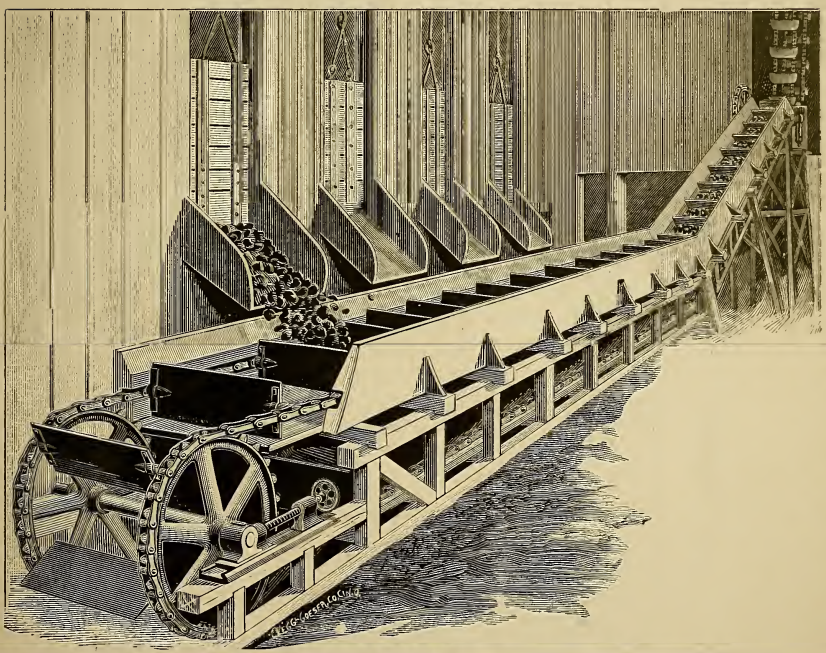
FIG. 1.—DRIVING MECHANISM OF THE HUNT CONVEYOR.

bucket the proper quantity of material. It operates very rapidly and is suitable for any material up to the size of broken coal.

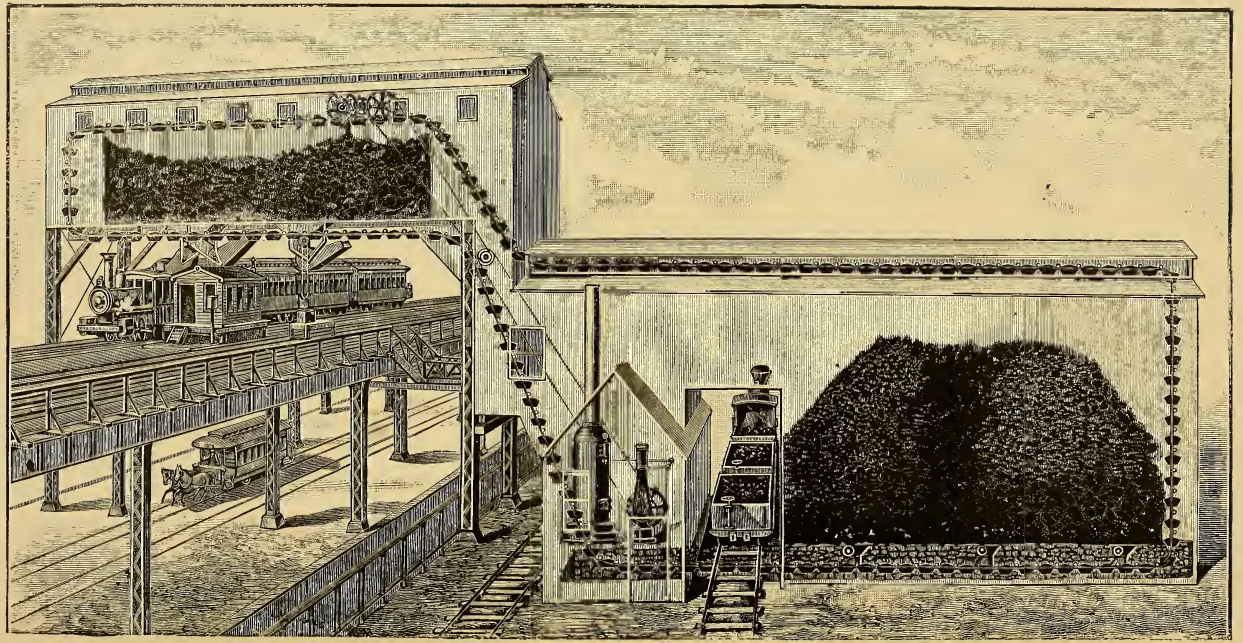
Several can be used in succession for measuring and mixing materials, each putting in the buckets a definite quantity of the material. The first one may put in broken stone, the second sand, the third cement, the fourth water. In this case each conveyor bucket contains all the ingredients in the proportions required by the engineer in charge, who adjusts the capacity of each filler, and the result is not dependent on the skill and care of the workman. As the buckets dump in succession, the materials will be fairly well mixed when they enter the mixing machine.

The "spout filler" is a continuous feed, the material running into the buckets, each one filling as it passes. This is suitable for all materials and is especially so for bituminous coal having large lumps. No matter how large the lumps are, a machine can be made large enough to handle them with ease.

The chain is composed of very heavy wrought-iron links. On the axle to which the links are attached are wheels having a flange like ordinary railway wheels. The axle can be thoroughly lubricated so that the bearings are as durable as in other machinery used in manufacturing establishments. The long links make but few joints for lubrication. The wheels of this chain run on a track similar to an ordinary railway, and as the conveyor is an endless chain it is always in equilibrium when not carrying materials, and the force to move it is only the force required to overcome the friction from the weight on the wheels. The coefficient of friction is greater than that in ordinary railways, but still it is comparatively small at the greatest, as all



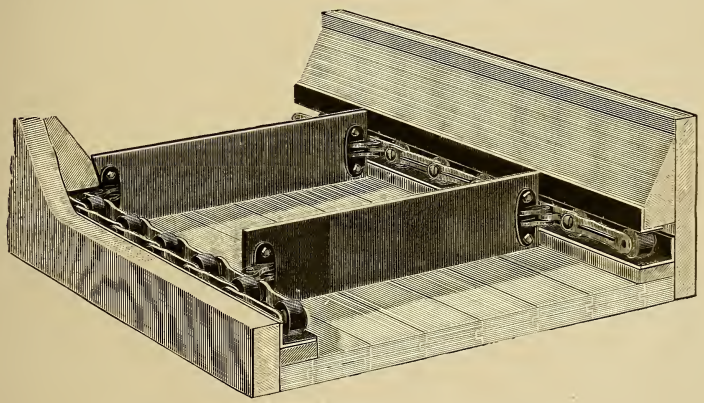
THE JEFFREY COAL CONVEYOR. MADE BY THE JEFFREY MANUFACTURING COMPANY, COLUMBUS, OHIO.



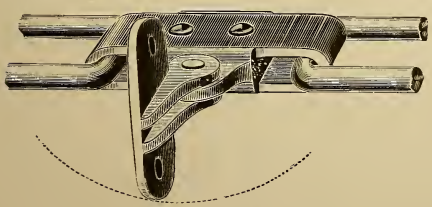
CONVEYOR AT EAST NEW YORK STATION OF THE BROOKLYN ELEVATED RAILROAD. CONSTRUCTED BY THE C. W. HUNT COMPANY, NEW YORK.

the parts are thoroughly lubricated. In the conveyor of the Brooklyn Elevated Railroad, the coal for coaling the locomotives is taken from the pile in the yard and carried up into the pocket over the elevated railway a vertical height of sixty-nine feet, and the horse-power actually used in the running of this machine under ordinary conditions of service is 10 horse-power. In combination with this conveyor, it will be observed, are chutes so arranged that the action of folding them up recharges them with a given quantity of coal and upon being pulled down the load is spouted into the tender and again folded up where it is clear of passing trains and the heads of careless brakemen. To the practical railroad man it will be readily apparent that there are many advantages in placing a coaling plant across a line of railroad, for, having chutes over each track, an engine loses no time in taking a special liding but can coal on the track where it happens to be. The coal is here lifted a vertical height of sixty-nine feet and the power required to do this is about 8 horse-power under ordinary conditions of service.

The chain is run at a very low speed and the capacity obtained by having large buckets. This makes a more expensive machine, but adds correspondingly to its durability and satisfaction in use. The ordinary size chain with buckets carrying two cubic feet of material runs at a speed of fifteen buckets per minute or about forty tons of coal per hour. Should the business temporarily require a greater capacity, the speed can be increased up to twenty-five buckets per minute without difficulty, giving a capacity of about eighty tons of coal per hour; but if the amount to be handled is above the normal capacity, a machine with larger buckets should be used. If the work to be done is smaller, the speed can be reduced to correspond.



THE JEFFREY CHAIN CONVEYOR.



DETAIL OF CHAIN OF JEFFREY CONVEYOR.

Instead of being driven by sprocket-wheels, the conveyor illustrated is driven by pawls pushing the chain along (Fig. 1). In this manner is obviated entirely the wear of the sprocket-wheels and of the chain. This method gives a motion that is evener and steadier and also permits the power to be applied to any part of the chain wherever is most convenient. The wear on the chain is

an insignificant amount, it is claimed, owing to the links being oiled in the joints, consequently it should not be affected much by wear as when first started.

In coal-yards it is especially suitable, as it will carry the coal horizontally or at any angle with equal facility. By carrying one part of the chain over the pile and the other beneath the pile, one conveyor will both take the coal up and store it in the building, and when the coal is wanted the lower part of the chain takes it out of the pile and delivers it to a pocket, or makes any other disposition of it desired.

Gas companies can also make a remarkably useful application in carrying both the coal to the generator and the same machine carrying the ashes and refuse out. The whole machine occupies no valuable space, being carried beneath the floor or underneath the roof, as has been mentioned. The illustration shows that the conditions and surroundings could be changed to almost any extent and the conveyor be just as applicable as it evidently is here.

The loading of vessels is another most important application of this machine. The coal can be dumped directly into the conveyor running underneath the track, then carried vertically high enough to clear the freeboard of the vessels, then run over to the hatch and vertically downward into the hold and the buckets dumped at the lower turn within two feet of the coal in the hold of the vessel. The coal gets only the breakage of falling from the car-hopper to the track, a distance of about three feet, and the dumping of the bucket in the hold of the vessel about three feet. The coal is put aboard as carefully as though a workman carried it from the car down into the hold of the vessel in a basket. For soft coals going to a market requiring lump-coal the saving in merchantable coal would justify almost any expenditure.

The handling of coal on ocean steamships is a work that now requires a greater tax on human energies than any other occupation; the most laborious work in heated air, confined space, and a pitching and rolling vessel. The conveyor carries the coal from the bunkers to the boiler-room and delivers it at any desired height. On merchant steamships it saves the great expense of "coal-passers"; on naval vessels it permits the carrying of a much larger crew that will be available in action, a time when every available man is wanted for service, and not to perform the work that steel and forethought should be arranged to do.

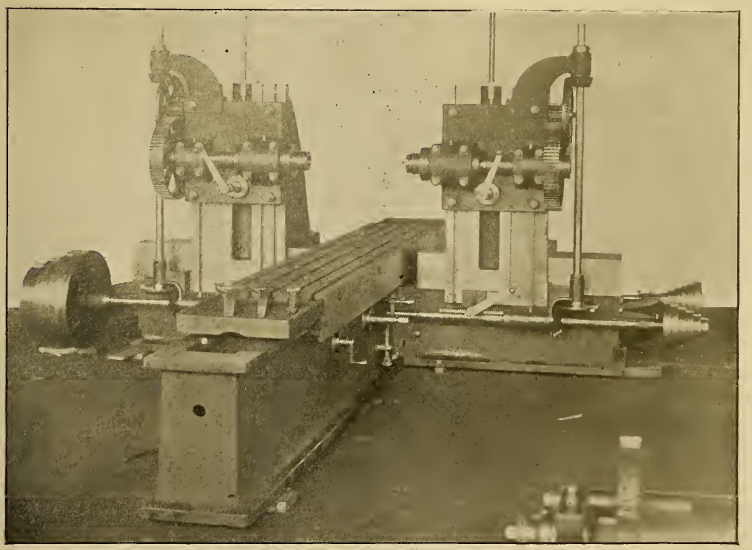
A DOUBLE-HEAD MILLING MACHINE.

THE engraving on next page represents a double-head milling machine designed by the Pratt & Whitney Company, of Hartford, Conn. Some months ago the *Iron Age* printed some information about a very heavy cut made on one of these machines. The cut was made in a locomotive parallel rod. The amount of metal removed in one cut measured $3\frac{1}{2}$ inches wide by $1\frac{3}{16}$ inches deep in the finished channel, plus the amount of metal at the top, $\frac{1}{8}$ inch deep by $4\frac{3}{4}$ inches wide, representing a section removed of nearly $4\frac{1}{2}$ square inches. The cutting was made at the rate of $1\frac{3}{4}$ inches per minute, or about 8 cubic inches of metal were removed per minute.

In milling cast-iron a feed of 9 inches per minute, with depth of cut of $\frac{1}{4}$ inch, and over a surface six inches wide, has been easily accomplished, the surface, of course, not being exactly a smooth one, but sufficiently so for roughing purposes, and as the table is reversed by power, a finishing feed may be taken with lighter feed and cut without the loss of time necessary where the cutter works in one direction only. The table feeds in either direction and has a quick re-

verse motion ; the reversing mechanism is inside the bed ; the lever for operating the same is placed convenient to the workman, where he can see the work, and have control of the quick traverse instantly. It is hardly necessary to adjust the table except by power, although the machine is provided with hand-adjustment also. The machine is of sufficient strength and rigidity to feed cutters both

nor is 8 cubic inches of steel or wrought-iron per minute, for with the available range of speeds and feeds much more can be done, and with this double-head machine, using two milling heads, each 20 inches in diameter, with inserted cutters, the capacity is greatly increased and the results quite enough to show an advance in design and effectiveness of this class of machine tools.



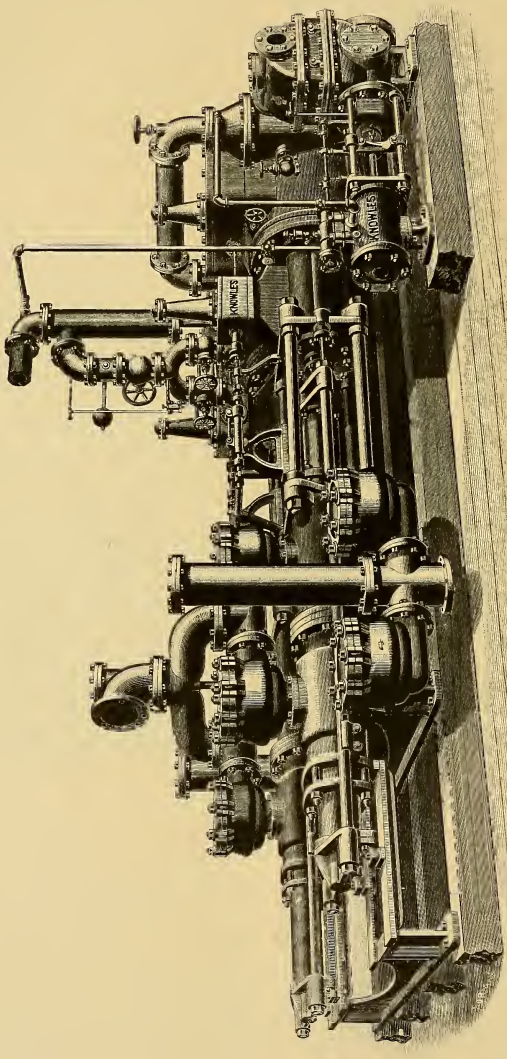
DOUBLE-HEAD MILLING MACHINE. CONSTRUCTED BY THE PRATT & WHITNEY COMPANY, HARTFORD, CONN.

with and against the work, being practically without backlash.

The best result in roughing, both as to the endurance of the cutter and the effective power of the machine, is obtained by running the cutter with the feed.

A removal of 13½ cubic inches of cast-iron per minute is not by any means the limit of the capacity of the machine,

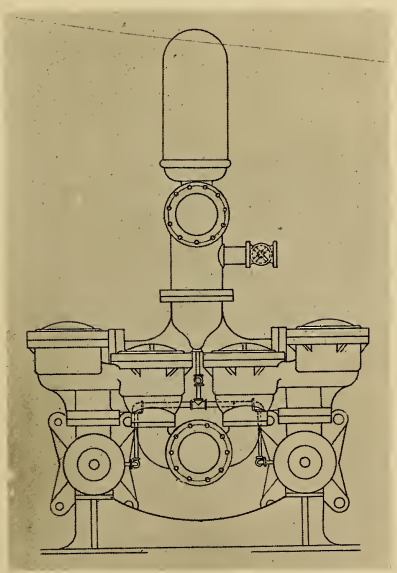
The machine has horizontal and vertical adjustments on both heads ; the greatest height of the spindle from the table is 25 inches, the distance between the ends of the spindles 6 to 56 inches. The front journal is 5½ inches in diameter by 10 inches long. The weight of the machine with 10 feet travel is 21,800 pounds. It is also made with a single head and foot-block.



COMPOUND CONDENSING PLUNGER POT-VALVE MINE PUMP. CONSTRUCTED BY THE KNOWLES STEAM PUMP WORKS FOR THE ARGENTUM-JUNIATA MINE, ASPEN, COL.

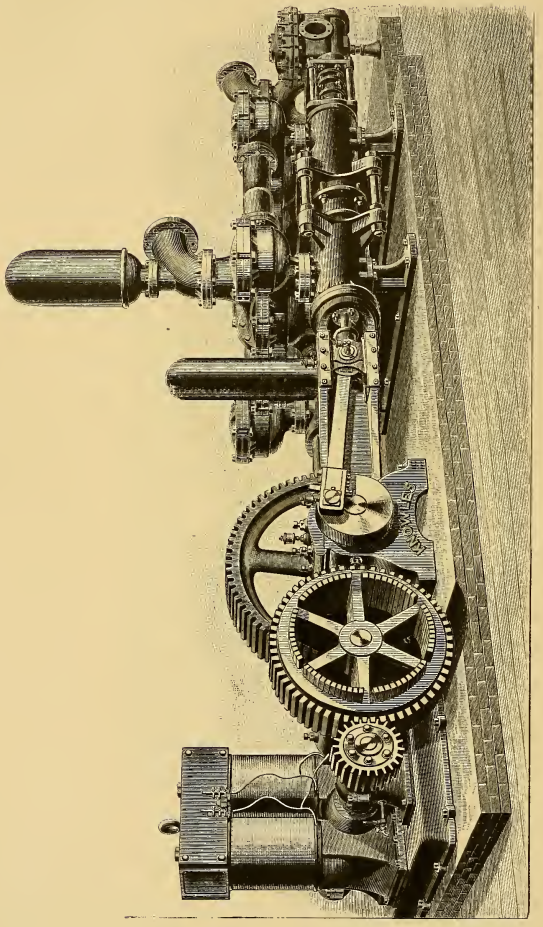
SOME NEW MINE PUMPS.

THE illustration on opposite page shows a compound condensing duplex outside packed plunger pot-valve mine pumping-engine, built by the Knowles Steam Pump Works. There are two high-pressure steam cylinders 22 inches in diameter, two low-pressure steam cylinders 40 inches in diameter, and four 12½ inches in diameter outside packed plungers. The stroke of all is 36 inches.



END ELEVATION OF ELECTRIC POWER PUMP.

The working-barrels are four in number, each pair bolted together with a composition partition plate. The plungers are four in number and work through packed stuffing-boxes at each end of the working-barrels. The cross-heads on plungers are fitted with shoes and guides for carrying the weight of the plungers off the stuffing-boxes and glands. The valve-chambers are of the pot form, eight in number, four being for suction and four for delivery. The valves and seats in these chambers are brass and faced with medium hard rubber, put on in such a manner that they can be readily removed. All the valves in each chamber are got at through the cover, which is arranged with hinge bolts for giving quick and easy access to the valves. The suction valve-chambers are on the side and are connected together with a cross and fitted with suction air-chamber. The discharge valve-chambers are on top and connected together with cross-pipe and discharge elbow.



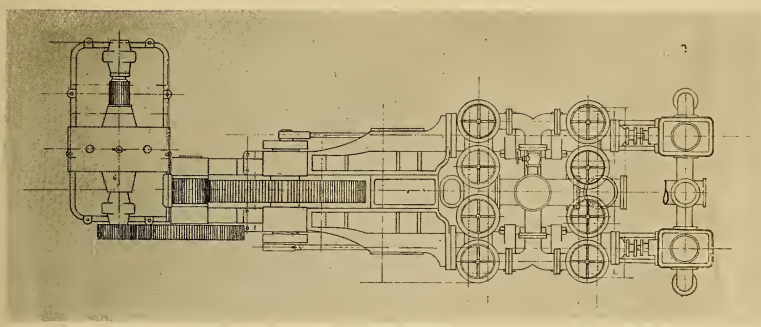
ELECTRIC PUMP WITH EDISON MOTORS. CONSTRUCTED BY THE KNOWLES STEAM PUMP WORKS FOR THE "POOR MAN" MINE, BURKE, IDAHO.

The steam cylinders are connected to the water cylinders by heavy wrought-iron tie-rods which gives free access to all the stuffing-boxes.

The high- and low-pressure steam cylinders with their heads, etc., are steam-jacketed. Slide-valves are balanced. The valve-gear is very heavy and strong. The engine is fitted with a steam separator, main and side throttles, sight-feed lubricator, cross exhaust, and the exhaust from the low-pressure cylinders is piped to the condenser.

The air-pump and condenser is of the independent pattern, especially adapted for mine use, being very compact.

diameter water-plungers, 12-inch stroke, complete with a 100 H.P. Edison motor. It is now running and delivering 500 gallons of water per minute to an elevation of 500 feet in one lift. The pump is placed on the 500-foot level in the mine, and the electricity is conveyed from water-power some 5 miles distant. The pinion on the motor-shaft is cast-steel, machine-cut; it works into a mortise-wheel on the intermediate shaft. On the intermediate shaft is a pinion-gearing into the large spur-wheel on the crank-shaft. The latter are machine moulded. The crank-shafts and intermediate shafts work in very heavy bear-



PLAN VIEW OF ELECTRIC POWER PUMP.

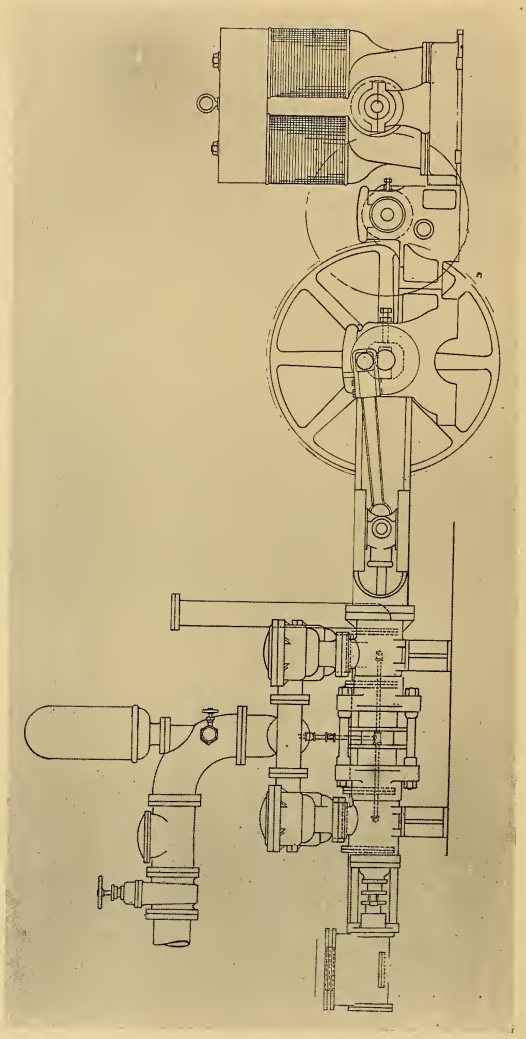
The steam cylinder of the air-pump is 14 inches in diameter. The diameter of the vacuum cylinder is 20 inches and the stroke 24 inches.

This pumping-engine is working in the Argentum-Juniata Mine, Aspen, Col., delivering 1200 gallons of water per minute to an elevation of 600 feet in one lift. It runs free from all shock or jar and is giving excellent satisfaction.

The illustration on opposite page represents a duplex outside packed plunger pot-valve electric-power pump, recently built by the Knowles Steam Pump Works for the "Poor Man" Mine, at Burke, Idaho. It has two 9½-inch

ings,—cranks are of the disc pattern. Crank and cross-head pins are steel; heavy wrought-iron connecting rods. Entire water-end is made of charcoal-iron, dry sand castings; plungers are of hard iron, working between the working-barrels and fitted with stuffing-boxes.

The valve-chambers are independent castings, four being for suction and four for the delivery. The valve-seats and valves are of hard composition faced with leather. The pump makes 35 revolutions, runs absolutely smooth, free from all shock or jar, and is giving excellent satisfaction.



SIDE ELEVATION OF ELECTRIC-POWER PUMP FOR "POOR MAN" MINE.
(See page 502.)

Reflections and Observations.

THE other day a man was brought into court charged with practicing medicine without a diploma or license.

It seems he had obtained several hundred dollars from a patient which according to an agreement was to be paid if he recovered from his illness. As part of the treatment consisted of stealing a a piece of raw meat and hiding it in the cupboard until it was decayed, by which time the cure was to be effected, it dawned upon the sufferer that he was in the hands of a quack, so he made a complaint and endeavored to recover the money he paid, alleging that the man had no right to put the initials M.D. after his name.

The alleged physician was arrested and at court contended otherwise, saying that he never claimed to be a physician.

"What do you mean, then," asked an attorney, "by the initials M.D. on your card?"

"Oh, they only mean mechanical dentist."

It may be added, the judge held him in bail for further examination.

**

AT the water-works at Fairmount Park, Philadelphia, a race is arranged to run turbine wheels and although there are lots of water wasted, as there is plenty of it, the saving in coal is considerable. The noise in the power-house when all the wheels are running is terrific and reminds one of a dozen old fashioned flour-mills at work. The other day a countryman who was seeing the sights went out there and after listening to the noise for some time, said, "Well, I allus heered that these Quaker folks were perticular, but I never knew they grinded their water before."

**

SOME weeks ago I was in Chicago, and there met an old classmate who I had not seen for a number of years. After talking about the World's Fair, smoke nuisance, and other topics of the day, I suddenly remembered that my friend had been accompanied on a European trip with another classmate, who I also knew but had lost sight of for some years.

"Where is Harry?" I asked.

"I haven't seen him for some years," he replied.

"Well, have you any idea where he is?"

"Yes, I have my suspicions."

"What do you mean?"

"Oh, he died last August, you know."

**

AN engineer who was sent to a small town to set up a Corliss engine was obliged to stay at a boarding-house where variety in the fare did not seem to be an essential consideration. As the town was in Massachusetts, of course beans played quite a prominent part in the programme, and long before the engine was running and adjusted the engineer was thoroughly disgusted. Happening to meet an acquaintance

after his return to New York, he told him of his experience.

"What disease did you catch there?" he asked.

"No disease that I know of," he replied.

"Well, you're lucky, for not long ago I had stopped at a hotel in Wisconsin and they gave us liver every day. Before I left I had complained of it so much that the proprietor told me I had contracted a bad disease.

"What is it?" I asked.

"The liver complaint," he replied.

+ +

OUT in Erie, as everyone knows, there are several establishments where many boilers are built, the Erie City Iron Works shipping last year, it is said, nearly 2000. A few weeks ago, while I was standing at the depot there, waiting for a train, I saw a couple of men in overalls and grease sitting on the platform and talking about boilers. I went up to them and asked them how work was.

"Pretty good," replied one of them, whose name was Pat.

"Do you know how many boilers the Erie City Iron Works built last year?" I asked.

"I dont know exactly," he replied, "but I heard it said they made something like two thousand."

"More than two thousand," interrupted his companion; "more than that, Pat."

"How many?" I asked.

"I heard 'em tell the other day, and it's a good deal more than two thousand: it's over f-i-v-e hundred!"

+ +

A FEW weeks ago I was at Niagara Falls, examining the new tunnel being built for the water-power, the electrical transmission of which has upset the heads of everyone in the vicinity of Buffalo. Land which was offered for $50 an acre and no takers is now finding plenty of purchasers at $800 to $1000.

Standing near the elevator, which was to take some sight-seers down, was an old lady. She was very timid, and although urged by her companions to "come along," declined to do so. Just as the car started she turned to the man in charge and said,—

"Suppose the rope would break?"

The man looked at her with a very serious countenance, and after figuring up the change he had, replied,—

"Oh, that would be all right; they all *paid* before they got aboard."

+ +

THIS reminds me of "When is an M.E. not an M.E.?" one of the questions I asked in these columns a few months ago, and a number of answers has made it certain that an M.E. is an M.E. when he is an M.E.

This may not be a conclusive argument, but it's so.

I notice that a number of engineers seem to give preference to the fact that they are "Member Am. Soc. M.E." in preference to the simple title of M.E.

This is, it seems, a good idea, and will be preferable perhaps unless there should be some compulsory law requiring all engineers who practice their profession to pass certain examinations and have granted to them the right to use M.E. This is not very likely to be done, however.

+ +

CHILDREN jump at conclusions, as you know, and at a lesson in natural history a little girl who evidently had already formed some idea of religion was instructed that cataracts and waterfalls are formed by water falling over a precipice.

When she reached home that afternoon, her mother, as usual, questioned her about her studies.

"What did you learn to-day?" she was asked.

"Oh, lots of things. The teacher told us all about Niagara Falls, and how the water is going to make trains go, and, ma, I found out how Niagara Falls were made."

"Tell me, my child," said the mother.

"Well, it was made by pouring water over a *Presbyterian*."

THE OBSERVER.

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